Preface

This booklet is an introduction to the exciting world of electronics. Following the "Learn by Doing®" concept, electronics will be easy to understand by using Snap Circuits to actually build circuits as you learn about them. This booklet emphasizes the practical applications of electronics, without bogging down in mathematics.

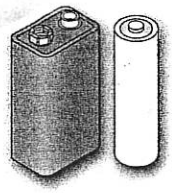
Why learn about electronics? Electronics plays an important and increasing role in our everyday lives, and so some basic knowledge of it is good for everyone. Learning about it teaches how to do scientific investigation, and the projects develop basic skills needed in today's world.

The first pages of the snap circuits project manuals contain a brief description of the parts in snap circuits, along with brief guidelines for building circuits.

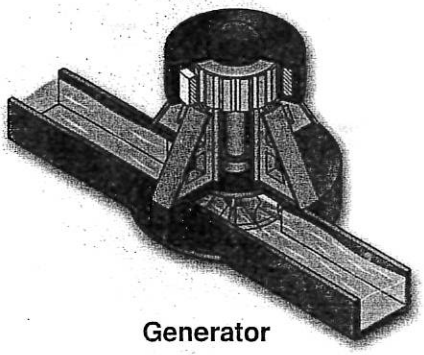
CHAPTER 1: BASIC COMPONENTS & CIRCUITS

Learn By Doing®

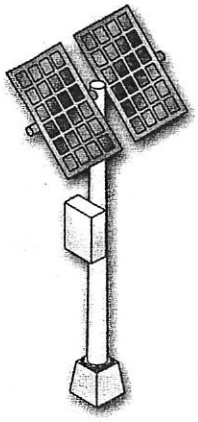
What is electricity? Nobody really knows. We only know how to produce it, understand its properties, and how to control it. It can be created by chemistry (batteries), magnetism (generators), light (solar cells), friction (rubbing a sweater), and pressure (piezoelectric crystals).



Batteries

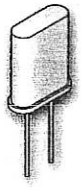


Generator



Solar Cells

Rubbing a Sweater

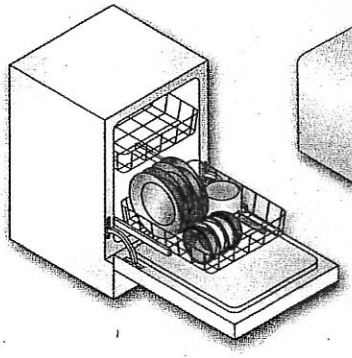


Piezoelectric Crystal

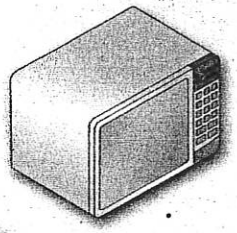
In this section you will learn about basic electrical components and circuits. By building circuits using Snap Circuits, you will begin to understand the electrical world.

Electricity is energy that can be used to save us effort (electric toothbrushes and dishwashers), heat things (electric heaters and microwave ovens), make light (light bulbs), and send information (radio and television). But electricity can also be dangerous if abused (electric shock).

Electric Toothbrush

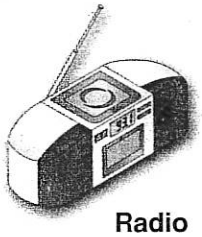


Dishwasher

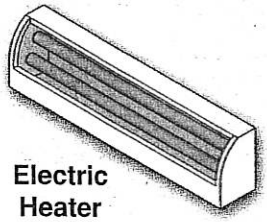


Microwave Oven

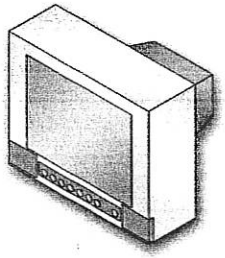
Light Bulb



Radio



Electric Heater



Television

Electric Shock

1-1 Electricity

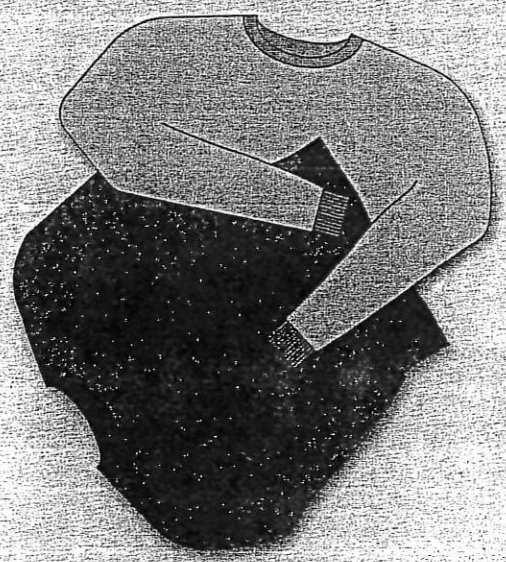
The name electricity came from the Greek name for amber, the material in which electrical effects were first observed. What do you think of electricity as being? **Electricity** is one of the fundamental forces of nature. At its most basic level, it is an attraction and repulsion between sub-atomic (very, very, very, very tiny) particles within a material.

This attraction/repulsion is referred to as an **electrical charge**; it is similar to and closely related to magnetism. These attractions/repulsions are extremely powerful but are so well balanced out at the sub-atomic level that they have almost no effect on our lives.

As an example, electrical attraction is about 1,000,000,000,000,000,000,000,000,000,000,000,000,000 times more powerful than gravity (gravity is what causes things to fall to the ground when you drop them). However electrical attraction is so completely balanced out that you don't notice it, while gravity effects are always apparent because they are not balanced out.

Gravity is actually the attraction between objects due to their weight (or technically, their mass). This effect is extremely small and can be ignored unless one of the objects is as big as a planet (like the earth). Gravity attraction never goes away and is seen every time you drop something. Electrical charge, though usually balanced out perfectly, can move around and change quickly.

For example, think about how two sweaters can cling to each other when you take them out of the dryer. This is due to an electric charge that has built up between them. There is also a gravity attraction between the sweaters, but it is always extremely small.



Electronics is the science of working with and controlling electricity. Many work-saving appliances like dishwashers, hairdryers, and drills are electrical but not electronic. Electronic products use electricity to control themselves, using parts like resistors, capacitors, and transistors. Electrical appliances are only controlled mechanically.

Most products you bring from your old house to your new house are electronic (such as TVs, computers, touch-tone phones, radios, most battery operated products), but not all (such as hairdryers, electric power tools).

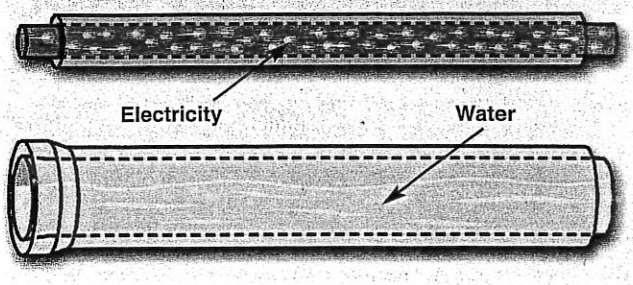
A good way to think of the difference between electrical and electronic products is to think about moving into a new house. Most products in the empty house are electrical (such as all the wiring and switches in the walls, rotary phones, dishwashers, electric ovens, air conditioners, most types of thermostats).

Electricity is the movement of sub-atomic particles (with their electrical charges) through a material due to an electrical charge outside the material. Electricity will be easier to understand if you think of the flow of electricity through circuits as water flowing through pipes.

1-2 Wires

Wires can be thought of as large, smooth pipes that allow water to pass through easily. Wires are made of metals, usually copper, that offer very low resistance to the flow of electricity.

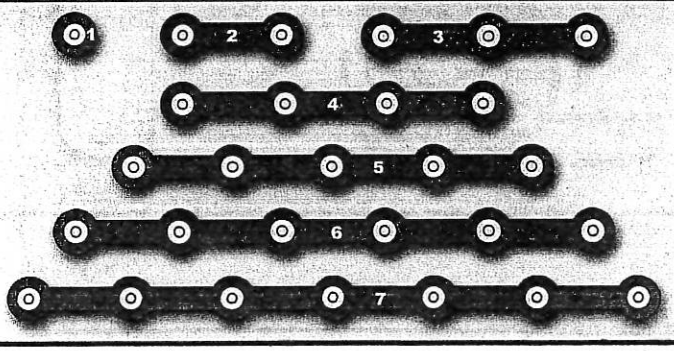
The **electric current** is a measure of how fast electricity is flowing in a wire, just as the water current describes how fast water is flowing in a pipe. It is expressed in **amperes** (A, named after Andre Ampere who studied the relationship between electricity and magnetism) or **milliamps** (mA, 1/1000 of an ampere).



With Snap Circuits the wires you will use have been shaped into snap wire strips, to make interconnection easy. These work the same as any other wires you might find in your house, since they are made of metal.

Introducing New Parts

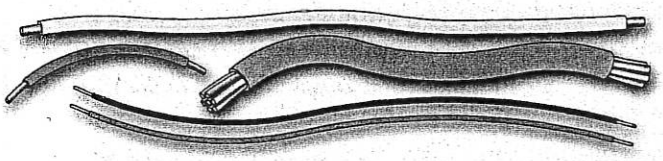
If you have the snap circuits parts nearby then pull out the wires and look at them. They have numbers such as 2, 3, 4, 5, 6 or 7 depending on the length of the wire connection. There is also a 1-snap wire that is used as a spacer or for interconnection between different layers.



Wires can generally be as long as desired without affecting circuit performance, just as using garden hoses of different lengths has little effect on the water pressure as you water your garden. However there are cases where the length and size of a pipe does matter, such as in the water lines for your entire city or in an oil refinery. Similarly, wire length and size are important for electric power lines transporting electricity from a power plant in a remote area to a city, and in circuits used in radio or satellite communication.

If you were to look inside an electronic device in your home (make sure it's not plugged in) you might see a lot of wires of different colors. The actual wires are all the same color of metal, but they have a protective covering over them. The colors are used to easily identify which wire is which during assembly and repair of the circuit.

The covering is also used to prevent different parts of a circuit from connecting accidentally.

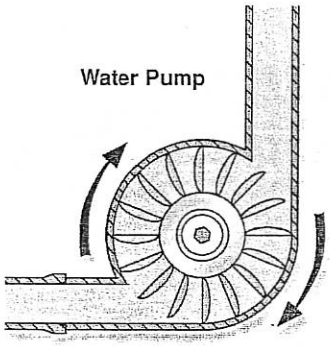


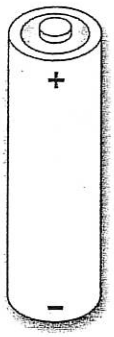
Try to imagine the total length of wire used in all the products in your home!

1-3 Batteries

To make water flow through a pipe we need a pump. To make electricity flow through wires we use a battery. A battery creates an electrical charge across wires. It does this by using a chemical reaction and has the advantage of being simple, small, and portable.

Voltage is a measure of how strong the electric charge from your battery is, and is similar to the water pressure. It is expressed in volts (V, and named after Alessandro Volta who invented the battery in 1800). Notice the "+" and "–" signs on the battery. These indicate which direction the battery will "pump" the electricity, similar to how a water pump can only pump water in one direction.



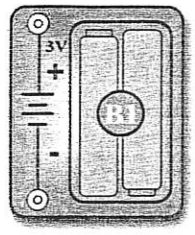


The 0V or "–" side of the battery is often referred t as "**ground**", since in house or building wiring it is connected to a rod in the ground as protection against lightning.

Battery power is much easier to use in electronics than the electricity that powers your home. This is because most electronic circuits only need a low voltage source to operate; all the electricity produced by your electric company comes at a higher voltage, which must be converted down. If a circuit is given too much voltage then its components will be damaged. It is like having the water in your faucet come out at higher pressure than you need, and it splashes all over the room. If water in a pipe is at too high of pressure then the pipe may burst. Batteries are selected to give your circuit just the voltage it needs.

Introducing New Parts

Your Snap Circuits uses two sets of two 1.5V batteries in a holder (snap part B1, actual batteries are not included). Notice that just to the right of the battery holder pictured below is a symbol, the same symbol you see on the battery holder. Engineers are not very good at drawing pictures of their parts, so when engineers draw pictures of their circuits they use symbols like this to represent them.



Battery Holder (B1)

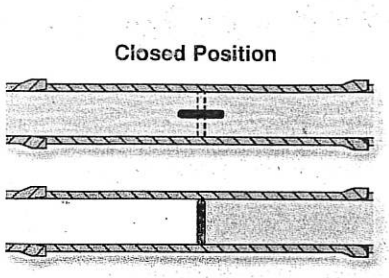
Battery Symbol

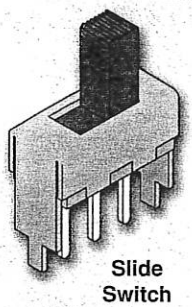
Batteries are made from materials like zinc and magnesium dioxide, electricity flows as these react with each other. As more material is used up by the reaction, the battery voltage is slowly reduced until eventually the circuit no longer functions and you have to replace the batteries. Some batteries, called rechargeable batteries (such as the batteries in your cell phone), allow you to reverse the chemical reaction using another electric source. That way the batteries can last through years of use.

Try to count how many batteries are in your home, your count will probably be low. Many products that use your house power also have batteries to retain clock or programmed information during brief power outages (such as computers an VCRs).

1-4 The Switch

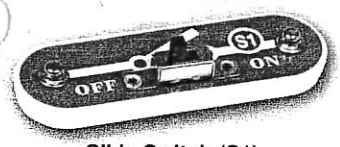
Since you don't want to waste water when you are not using it, you have a faucet or valve to turn the water on and off. Similarly, you use a switch to turn the electricity on and off in your circuit. A switch connects (the "closed" or "on" position) or disconnects (the "open" or "off" position) the wires in your circuit.




Slide Switch

Introducing New Parts

Just as the plumbing industry has a wide range of valves for different situations, there are many types of switches used in electronics. The type shown below is called a slide switch, because you slide it back and forth to turn it on and off. Snap Circuits includes one of these (part S1), shown below. As with the battery, the slide switch is represented by a symbol, shown to its right. If you have the snap circuits parts nearby, take out the switch and look at it.

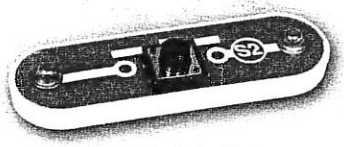


Slide Switch (S1)

Slide Switch Symbol

Introducing New Parts

Another type of switch is the press switch, and Snap Circuits also includes one of these (part S2). When you press down the two pieces of metal touch, so electricity can flow. When you let go of it, the electricity stops. Its symbol is marked on the snap part, though on many professional electronics drawings both slide and press switches use the symbol for the slide switch because they really perform the same function.



Press Switch (S2)

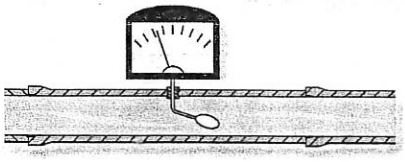
Press Switch Symbol

You can think of slide and press switches like the water faucet in your kitchen (which pours out water until you turn it off) and a water fountain in a school or movie theater (which only squirts out water as long as you are pressing the button).

Switches in modern electronics come in many diverse forms. Try to count how many are in your home or car; you will be amazed. There are slide, press, membrane, rotary, push-button, and other switches controlling nearly everything.

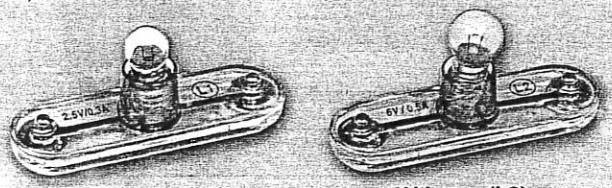
1-5 The Lamp

In a **lamp** electricity is converted into light, the brightness of the lamp increases as more electric current flows through it. You can think of a lamp as a water meter, since it is showing us how much current is flowing in a circuit just as a water meter shows how much water is flowing in a pipe.


Water Meter

Introducing New Parts

Snap Circuits includes two different lamps (parts L1 and L2, shown below). If you have the parts with you, take them out and look at them.



2.5V Lamp (L1) 6V Lamp (L2)

Just as there are different types of water meters to work with different pressures and volumes of water, there are also different lamps. Lamp L1 is a low-pressure meter, and works with voltages (electrical pressures) of up to 2.5V. Higher voltages than that will damage the bulb, so always make sure to use the correct lamp. Lamp L2 is for higher pressures of up to 6V, and won't be nearly as bright as L1 if the pressure is only 2.5V.

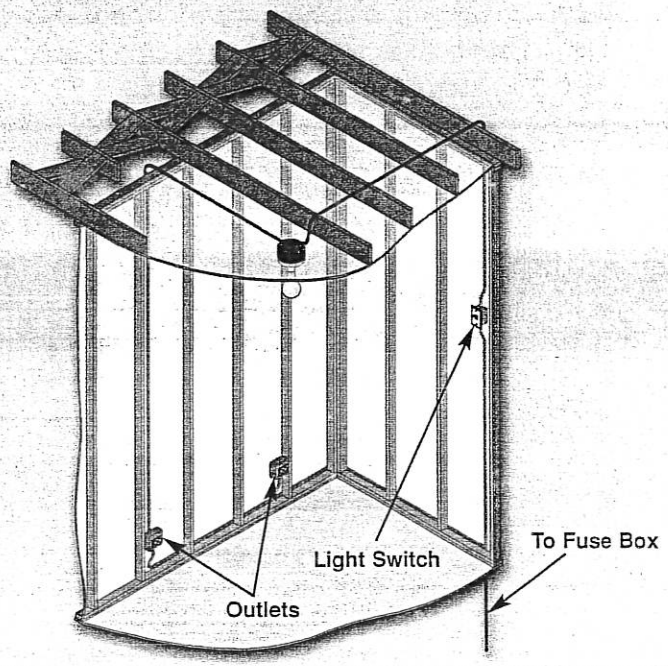
The electrical symbol for a lamp is shown here, it is the same for both lamps but the voltage will be indicated as needed. The lamp sockets are the same for both parts; only the bulbs and markings are different.

Lamp Symbol

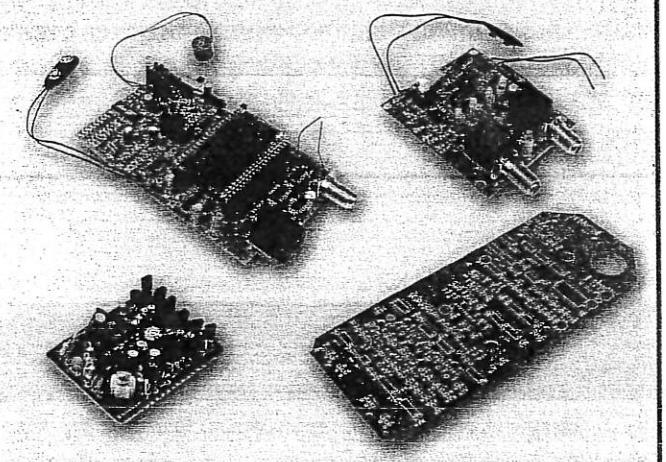
While occasionally lamps are used to indicate how much electricity is flowing in a circuit, they are mostly used to light our homes, businesses, and streets. Although scientists had been experimenting with electricity for years, the first practical use of electricity occurred when inventor Thomas Edison used it to light a bulb similar to these. For many years electricity was used almost exclusively for lighting. That has since changed. Now only a small percentage of the electricity produced in the United States is used for lighting with the rest going to a vast range of uses in everyday life that Edison would never have imagined.

1-6 The Base Grid

The water in your home flows through pipes mounted in the walls and floors of your home, and similarly the electricity in your house flows through wires mounted in the walls and ceilings of your home. But the wires in your walls take a lot of hard work to install and then can't be moved.



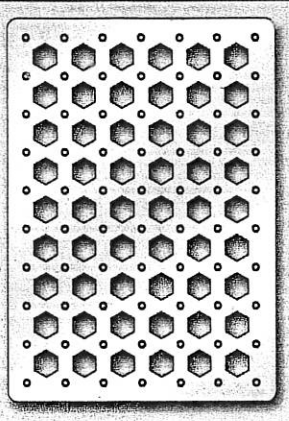
Most products that use electricity are small, easy to move, and easy to build. That is because they have almost all of their components and wires mounted on "circuit boards" such as these:



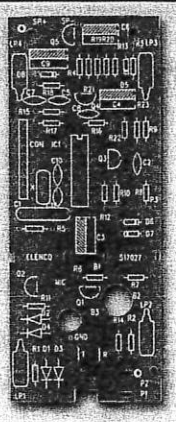
Boards like these are used in almost all electronic products, look inside any radio or computer and you will find them. Note that the "wires" connecting parts mounted on the circuit board are literally "printed" on the surface of the board; hence circuit boards all are called "printed circuit boards" or PCBs.

Introducing New Parts

In the same manner Snap Circuits uses a clear plastic base grid with evenly spaced posts to mount the snap parts and wires and to keep them together neatly. It has rows labeled A-G and columns labeled 1-10 to easily identify points in your circuit. You don't need the base to build your circuits, but just try building one of the larger circuits without it! The base grid is shown here, next to a picture of a typical circuit industry board before parts are mounted.



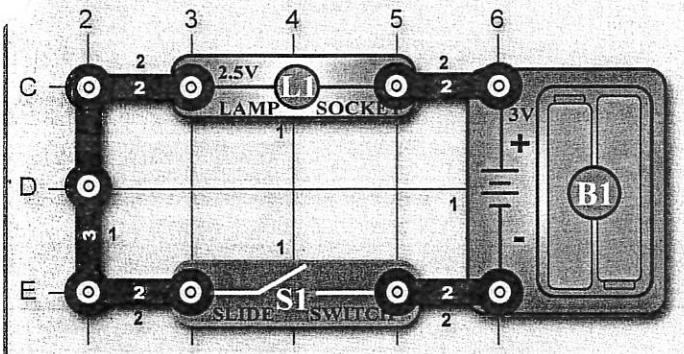
Base Grid

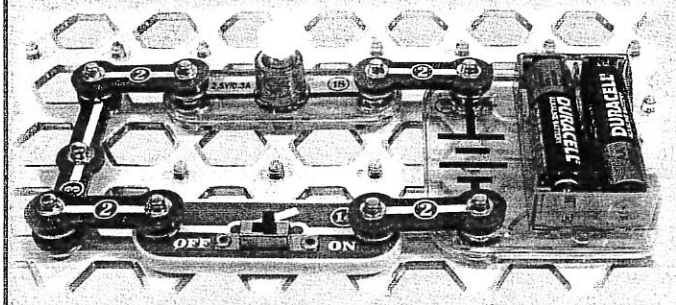


PC Board

Experiments

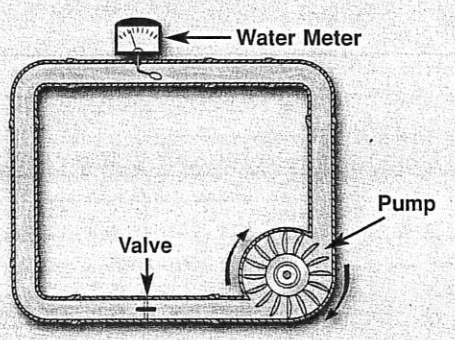
So far we've talked about wires, batteries, switches, lamps, and circuit boards; now it's time to put them together to form a circuit. Consider this circuit (which is project 1 on page 8 of the first project manual):





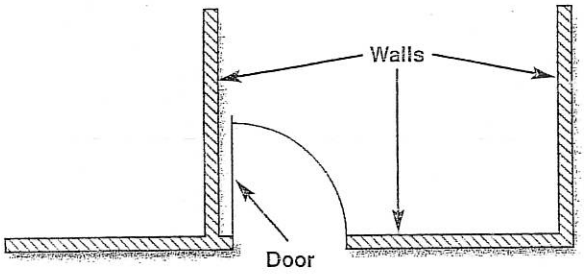
Turning on the switch turns on the lamp. This circuit is the same circuit used to turn on a lamp in your home. The only differences are the batteries are really power from the electric company, the lamp is larger and bright enough to light up the room, the switch is really a switch on the wall, and the snap wires are really wires in the wall and the cord to the lamp.

You can think of the electricity flowing through the battery, lamp, switch, and wires in the above circuit as if it were water flowing through a pump, water meter, valve, and pipes:



Note that each of the Snap Circuits in the project manuals has a box next to it ☐ so that you can mark off the circuits as you build them.

In electronics, the "on" position of a switch is also called the "closed" position. Similarly, the "off" position is also called the "open" position. This is because the symbol for a slide switch is similar to the symbol for a door in an architect's drawing of a room:



The electronics symbol for a slide switch should be thought of as a door to a circuit, which swings open when the switch is off. The "door" to the circuit is closed when the switch is on. This is shown here in drawings using the part symbols:

Open Switch (turned off)

Closed Switch (turned on)

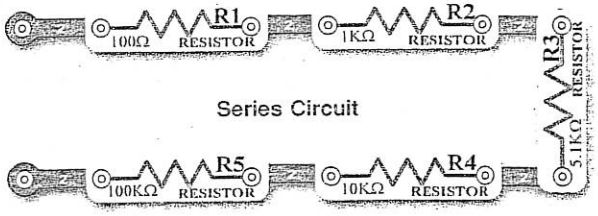
In case you haven't noticed, the batteries produce 3V and the lamp is made for voltages up to 2.5V. Don't worry, you will not damage your bulb. The voltage rating of the batteries (1.5V from each battery) is actually the voltage they produce when the electric current flowing from them is low, as the circuit current increases the voltage produced by the batteries is reduced. Think again of the lamp as a water meter - the lamp is bright so there must be lots of current flowing, hence the voltage is lower and the lamp is safe. You can see from the water diagram that with only a pump, an open valve, and a meter there is nothing to slow down the water flow and the pump will move the water as fast as it can.

Why does the battery voltage drop as current increases? Remember that a battery produces electricity from a chemical reaction. Not only is there a limited amount of the chemicals in a small battery (batteries slowly get weaker as you use them), but also not all of the material can react together at the same time.

If your instructor has a meter to measure voltage, ask him or her to measure the battery voltage with the switch on and off. You will see the voltage drop to under 2.5V when the switch is on.

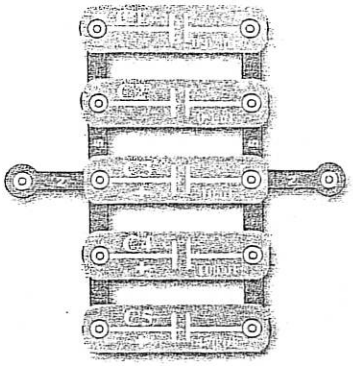
1-7 Series vs. Parallel Circuits

There are two ways of arranging parts in a circuit, in series or in parallel. Here are examples:

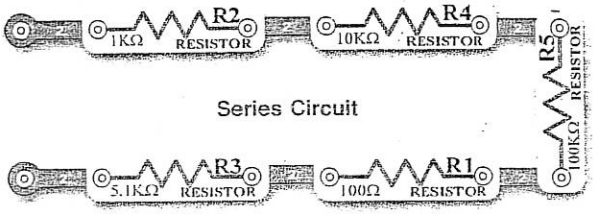


Series Circuit

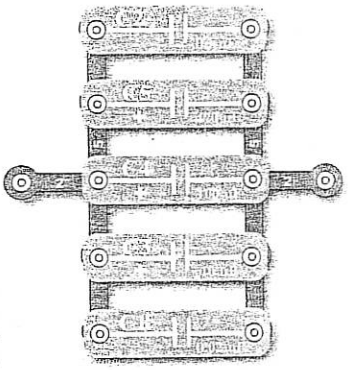
The parts within these series and parallel sub-circuits may be arranged in different ways without changing what the circuit does. So these sub-circuits are the same as the ones above:



Parallel Circuit

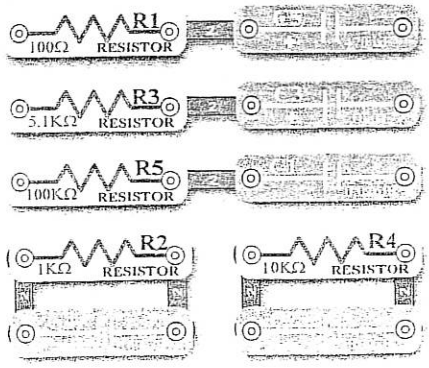


Series Circuit

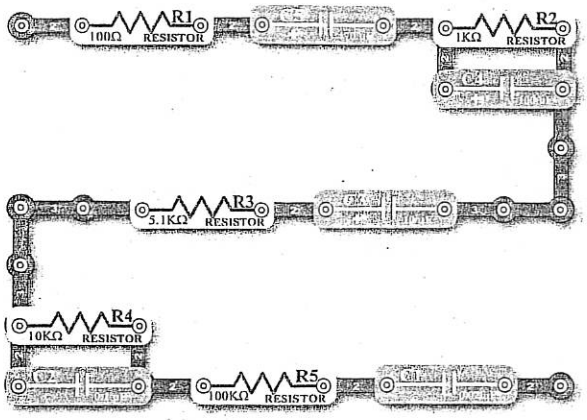


Parallel Circuit

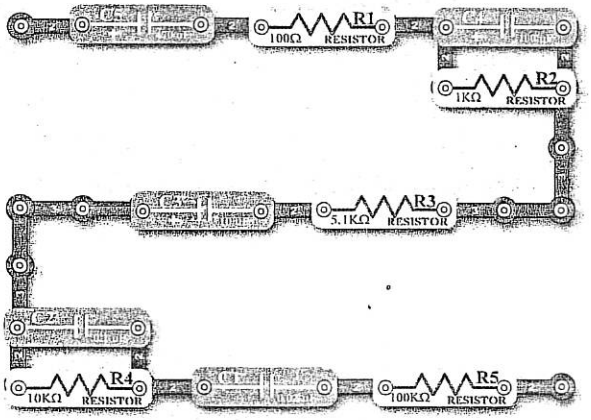
Large circuits are made of combinations of smaller series and parallel circuits. For example, these small sub-circuits:



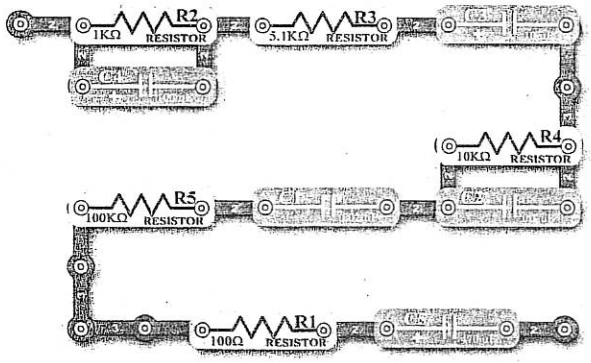
May be combined into this larger circuit:



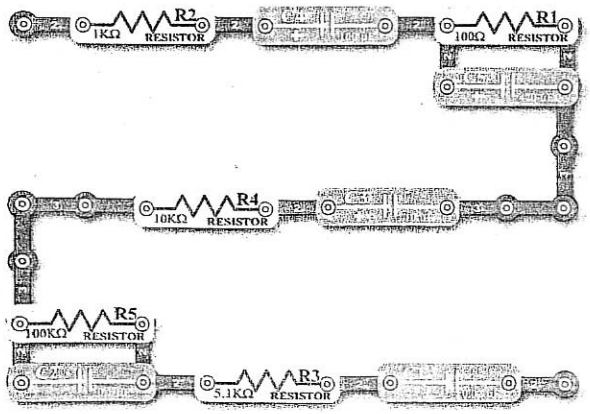
If you rearrange the parts in the sub-circuits, the circuit is still the same:



If you rearrange the order of the sub-circuits, the circuit is also the same:

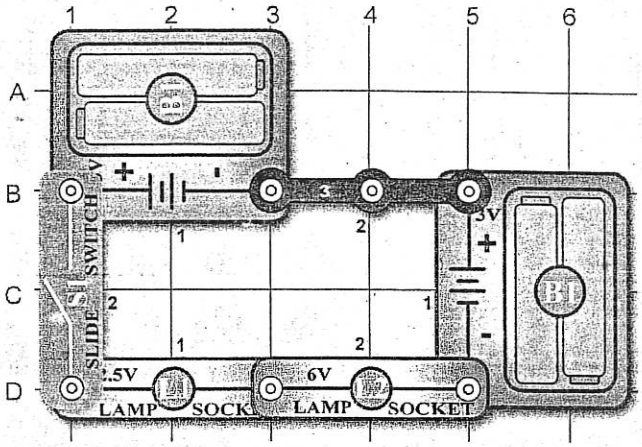


But if you rearrange the parts between sub-circuits, the circuit is different:



Experiments

Consider this circuit (which is project 152 on page 22 of the "Experiments 102-305" manual):



If the switch is on, both lamps will light. If one of the bulbs is broken then neither will be on, because the lamps are in series. The strings of small Christmas lights are wired in series; if one bulb is damaged then the entire string does not work.

This circuit uses two sets of batteries, these add together in a series circuit to produce 6V. Likewise, while 6V is well beyond the 2.5V rating of lamp L1, this voltage gets split between lamps L1 and L2 and so L1 will not be damaged. L2 is a 6V lamp made for higher voltage and current, so it will not be nearly as bright in this circuit as L1.

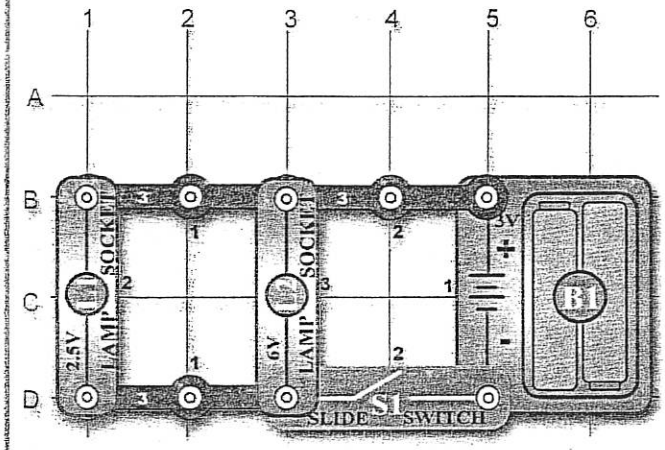
When the circuit has been off for a while, turn on the switch and watch the lamps closely. Notice how L2 takes longer to get bright while L1 gets very bright initially but becomes less bright as L2 turns on. Why?

Lamps like these are made with a special type of wire that gets hot enough to glow. L1 turns on faster because its wire heats up faster than L2's.

This effect may be easier to see if you replace one of the battery holders with a 3-snap wire.

Experiments

Consider this circuit (which is project 153):



If the switch is on, both lamps will light. If one of the bulbs is broken then the other will still be on, because the lamps are in parallel. Most of the lights in your house are wired like this; if a bulb is broken on one lamp then the other lamps are not affected.

In this circuit you could swap the locations of the lamps with each other (because they are both in parallel) or the batteries with the switch (they are both in series), but if you swap the switch with one of the lamps then the circuit will be different. All electric circuits are made up of combinations of series and parallel circuits, from simple ones like these to the most complex computers.

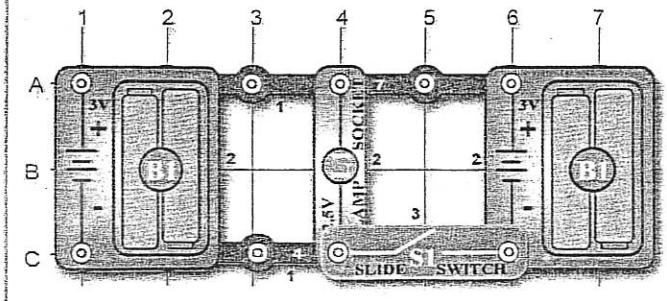
Note that in project 153 the lamps have the same brightness as in project 152 even though only one battery set is used. This is because the full battery voltage is applied to both lamps. This may seem more efficient than the method in project 152, but the current to light the lamps is the same so it is draining the batteries twice as fast.

For all of the snap circuits projects, the parts may be arranged in different ways without changing the circuit. The order of parts connected in series or in parallel does not matter - what matters is how combinations of these sub-circuits are arranged together. For example, in project 152 you may swap the locations of the switch or lamps without affecting the circuit operation in any way because they are all connected in series.

The choice of whether to use a series or parallel configuration in a circuit depends on the application, but will usually be obvious. For example the overhead lights in the rooms of your home are all connected in parallel so that you can have light on in some rooms and off in others, but within each room the light and switch are connected in series so the switch can control the light.

Experiments

Now consider this circuit (which is project 103):



With the switch off, the lamp will be bright even with only one set of batteries connected. If the switch is turned on then the lamp will be even brighter. This will be more apparent if the batteries on the left side are weak and those on the right side are new.

Batteries are placed in parallel when the voltage is high enough but the circuit needs more current than one group of batteries can supply. Think of each battery as a storage tank that supplies water. If you put two in parallel, you can get more water (current), but the pressure (voltage) stays the same.

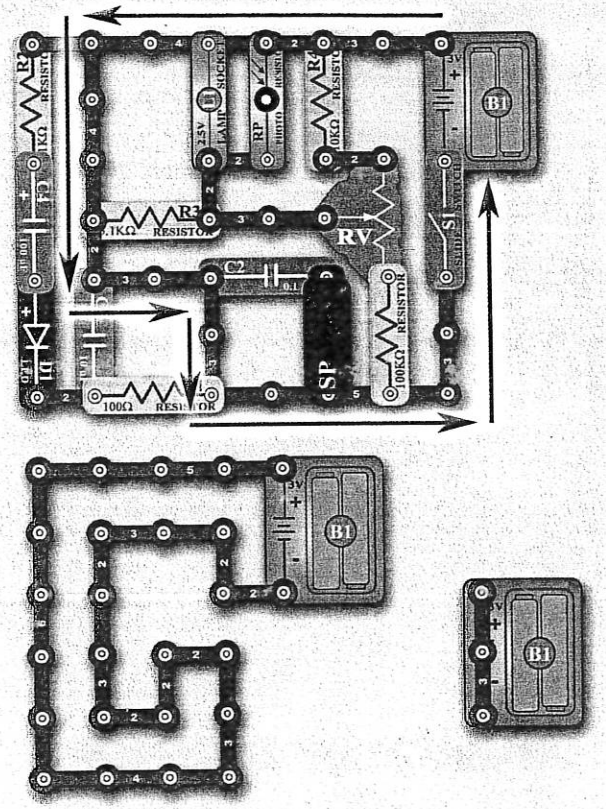
1-8 Short Circuits

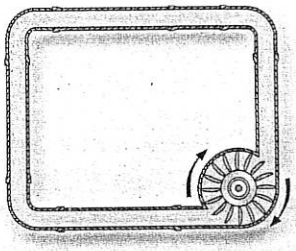
Every circuit will include a power source (the batteries), a resistance (which might be a resistor, lamp, motor, integrated circuit, etc.), and wiring paths between them and back. When wires from different parts of a circuit connect accidentally then we have a "**short circuit**". You've probably heard this term in the movies; it usually means trouble.

A short circuit is a wiring path that bypasses the circuit resistance, creating a **no-resistance path across the batteries. This will damage components and/or quickly drain your batteries.** Be careful not to make short circuits when building your circuits. Always check your wiring before turning on a circuit.

The name "short circuit" refers to how the current through the circuit bypasses (jumps around) other components in the circuit. It is the "easiest" path through the circuit, it is not always the "shortest".

Here are some examples:

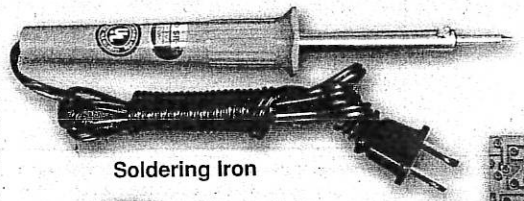




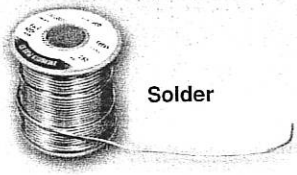
In a short circuit, there is nothing to limit the current in a circuit. However the chemical reaction in a battery cannot supply unlimited current, so the battery voltage drops to zero volts. This is called "overloading" the batteries. This overload produces heat and damages the batteries. Think of this as a pump pumping water in a loop as fast as it can until it burns out.

1-9 Solder

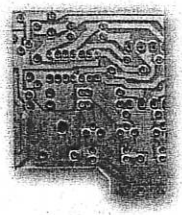
Solder is used to make electrical connections to components on a printed circuit board. It is a special metal made of tin and lead that melts at relatively low temperature (about 500°F). Solder is applied and melted around a joint where a connection is being made; it creates a solid bond between the metals.



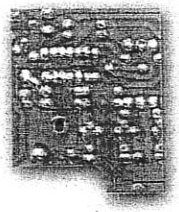
Soldering Iron



Solder

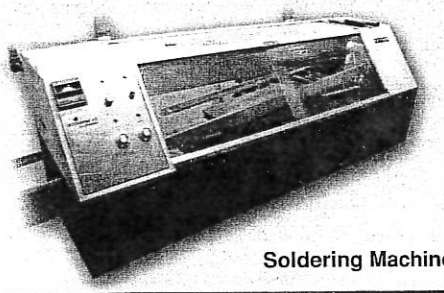


Before Soldering



After Soldering

The placement of parts onto circuit boards and the application of solder to connect and hold them in place are usually done automatically with special machines. In fact, the microprocessors used in modern computers are so finely designed that they are almost impossible to solder by hand.



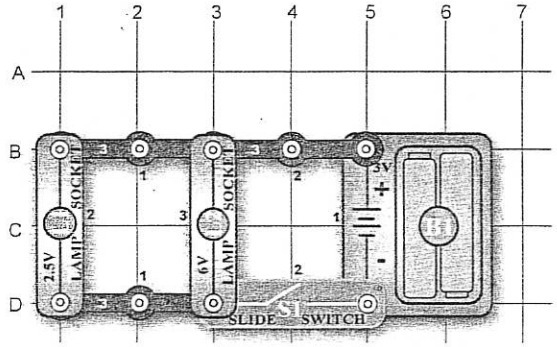
Soldering Machine

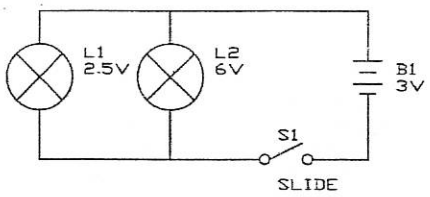
1-10 Schematics

The circuit diagrams in the snap circuits manuals are easy to understand and build your circuits from. But what if you wanted to write down your own circuit? These diagrams are not very easy to draw. There are also many ways of building the same circuit. For example, you could use a jumper wire instead of a 2-snap wire.

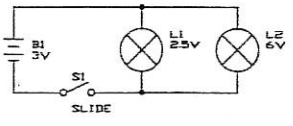
The snap circuit diagrams give you more information than you really need. They tell you how to build it, when all you really need to know is how it will work. You can find your own way to build it.

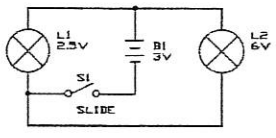
Notice the symbols marked on the parts. Those symbols are used in engineering circuit diagrams, which are called **schematics**. For example, snap circuits project 153 is shown here with an engineering schematic for it:

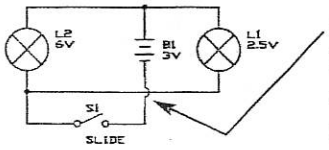




Schematics are easy to draw, and the part symbols used are international standards. Note that wires in a schematic are just lines, and can be as long as you like. Schematics are a flexible way of drawing circuits, and can be re-drawn in many different ways. For example, the above schematic could also be drawn as:

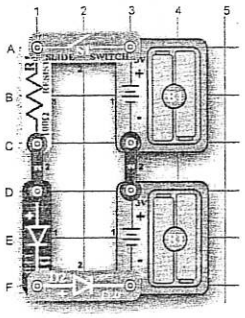


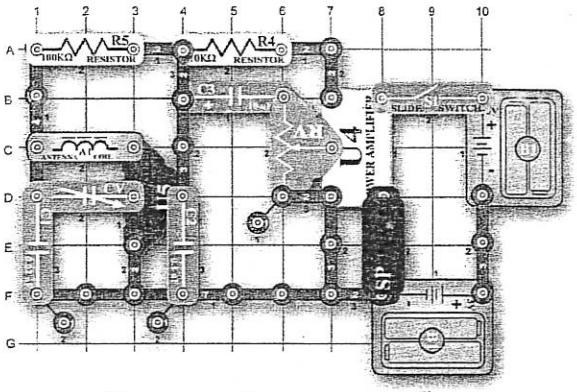


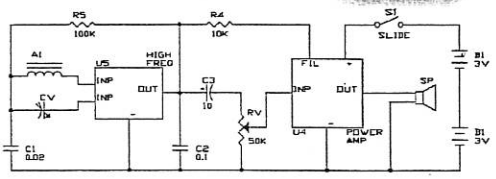


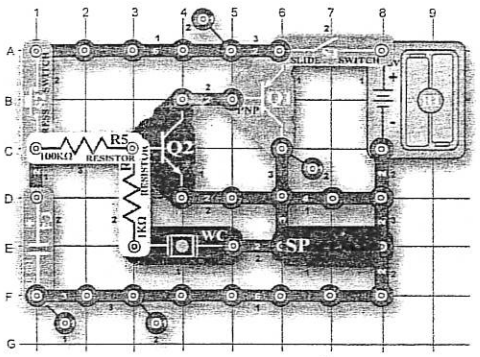
Note that ∩ represents two wires crossing over each other without connecting.

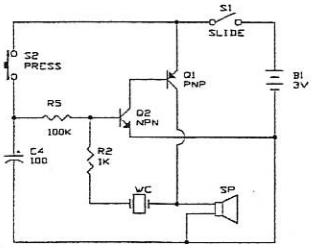
Here are some more schematic examples:











It is important to understand schematics, since many circuit designs are common and can be found in books. Almost all new circuits designed are similar to some circuit that already exists. Many products sold today come with schematics of their designs to assist in troubleshooting problems.

Quick Quiz

1. Draw a schematic for a circuit that consists of three lamps powered by a battery.
2. For each room in your home, make a schematic drawing showing how the lamps and switches controlling them are connected together.

Summary

Summary of Chapter 1:

1. The electric current is a measure of how much electricity is flowing in a wire, and is expressed in Amperes.

   The voltage is a measure of the electric pressure exerted into a wire or circuit by a battery or other power source, and is expressed in volts.

3. Switches are used to turn on or turn off the flow of electricity in a circuit.

4. A light bulb converts electricity into light.

5. Most electronic products have components mounted on circuit boards with the wires literally printed on the board surface.

6. Electrical circuits are all combinations of series and parallel configurations.

7. A short circuit is a no-resistance path across a power source, and causes damage to components and batteries.

8. Solder is a special metal that is melted to make solid electrical connections.

9. Schematics are engineering drawings of circuits using symbols.

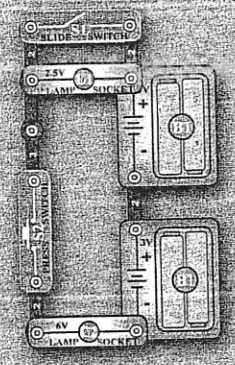
Quiz

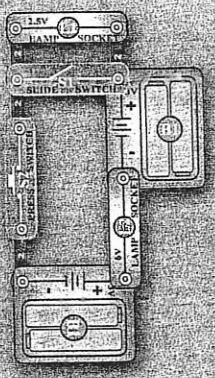
Chapter 1 Practice Problems

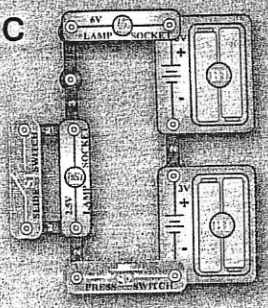
1. The flow of electricity is measured in _____.
   A. gallons B. minutes C. amperes D. volts

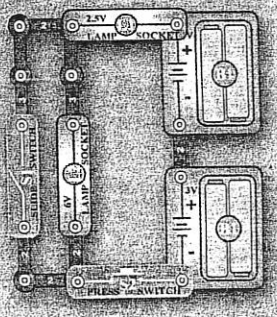
2. To turn on a switch, you _____ it.
   A. voltage B. open C. pressurize D. close

3. Three of the choices below are the same circuit with the parts arranged in different ways. Which choice is a different circuit?

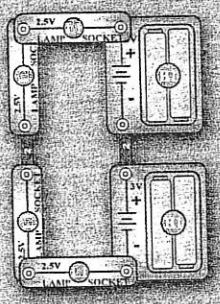
A 

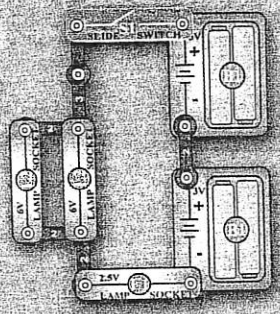
B 

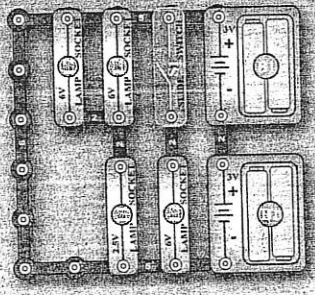
C 

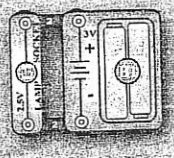
D 

4. Which of these is a short circuit?

A 

B 

C 

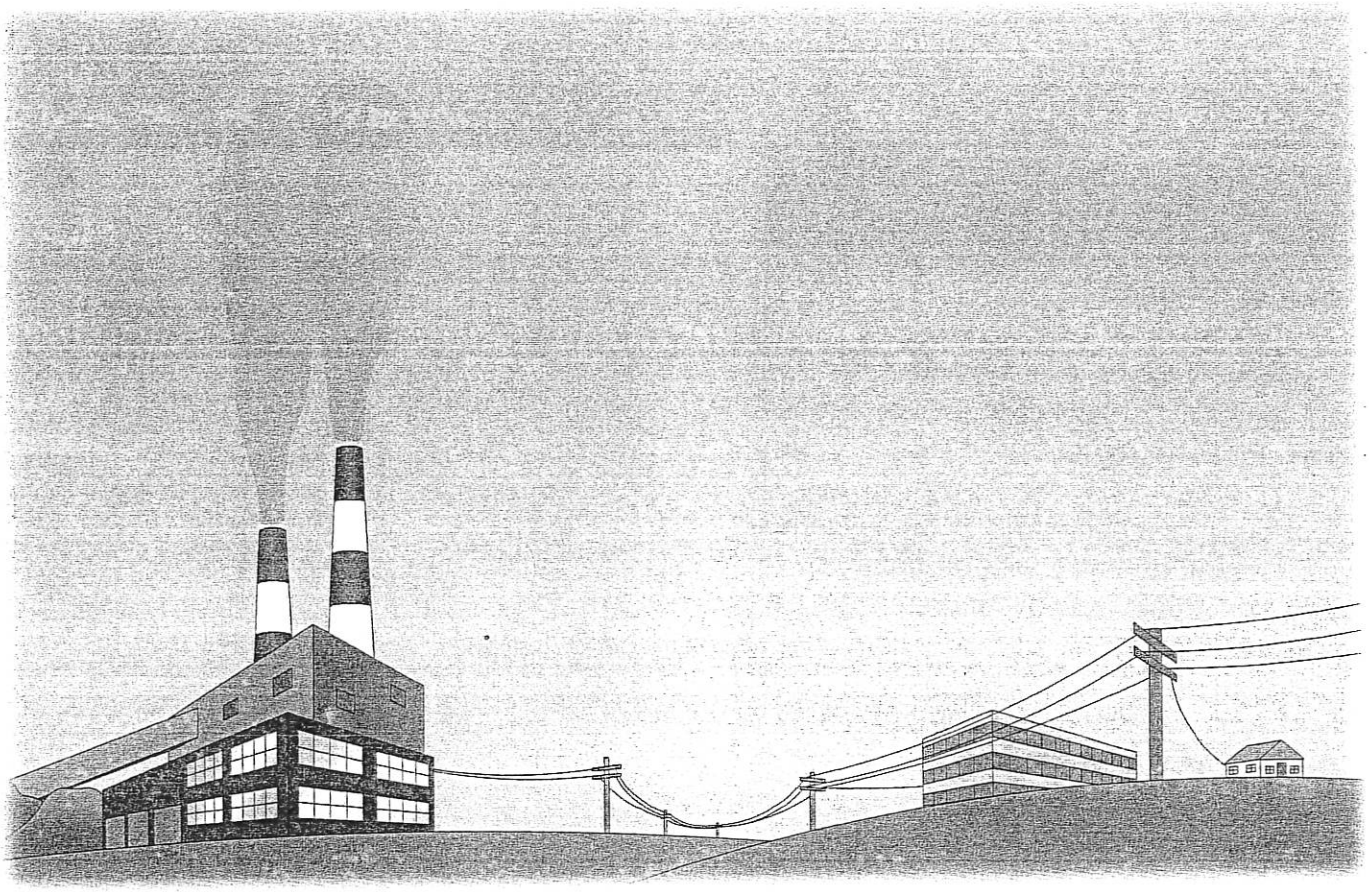
D 

Answers: 1. C, 2. D, 3. D, 4. C

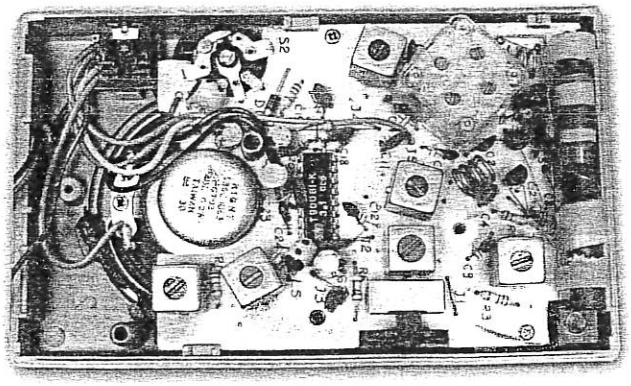
CHAPTER 2: MOTORS & ELECTRICITY

Learn By Doing®

In this chapter you will learn about generators and motors. A generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion. This statement may not seem important to you but it is actually the foundation of our present society. Nearly all of the electricity used in our world is produced at enormous generators driven by steam or water pressure. Wires are used to efficiently transport this energy to homes and businesses where it is used. Motors convert the electricity back into mechanical form to drive machinery and appliances. **The most important aspect of electricity in our society** - more important than the benefits of the Internet - **is that it allows energy to be easily transported over distances**.



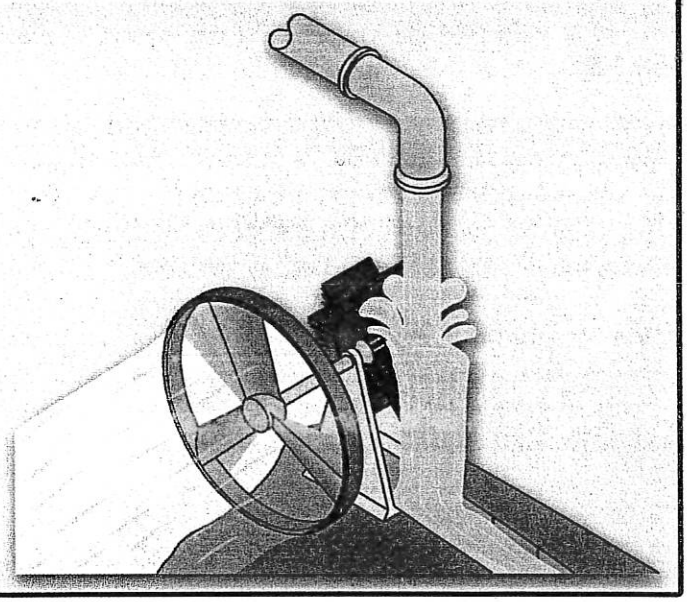
Note that "distances" includes not just large distances but also tiny distances. Try to imagine a plumbing structure of the same complexity as the circuitry inside a portable radio - it would have to be large because we can't make water pipes so small. Electricity allows complex designs to be made very small.



2-1 Motors

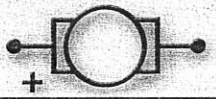
Water flowing under pressure in a pipe or a fast-moving stream can be used to turn a paddlewheel. If the paddlewheel was linked to a fan blade then you could use the water pressure to turn the fan, perhaps to cool yourself on a hot day. If the water was flowing very fast due to high pressure, then you could get the fan moving fast enough it might create a strong airflow like a propeller on a plane.

A similar thing happens in a motor, with electricity instead of water. A motor converts electricity into mechanical motion.

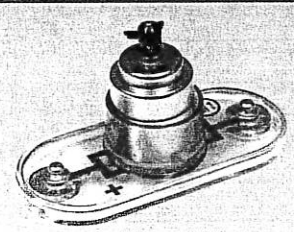


Introducing New Parts

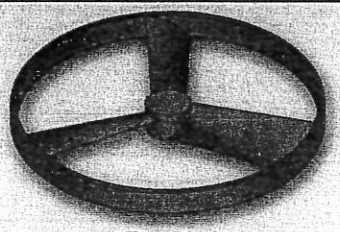
Snap Circuits includes one motor, shown here with its symbol. Snap Circuits also includes a fan, which is used with the motor. An electric current in the motor will turn the shaft and the motor blades, and the fan blade if it is on the motor.



Motor Symbol

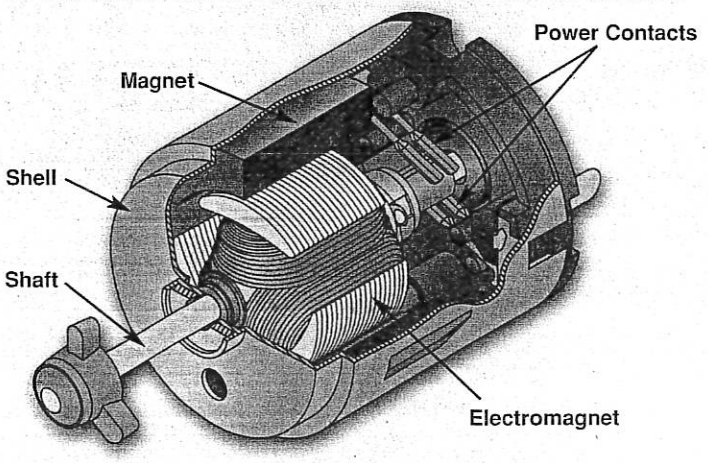


Motor (M1)



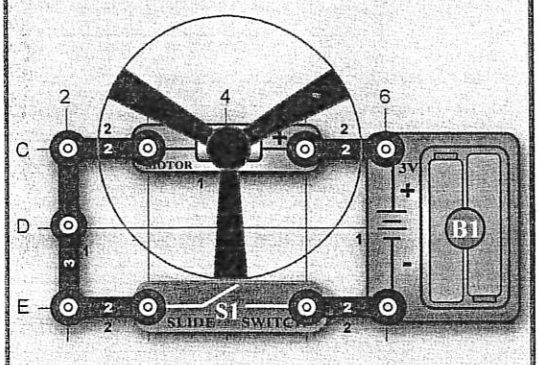
Fan Blade

How does electricity turn the shaft in the motor? The answer is magnetism. Electricity is closely related to magnetism, and an electric current flowing in a wire has a magnetic field similar to that of a very, very tiny magnet. Inside the motor is a coil of wire with many loops wrapped around metal plates. This is called an electromagnet. If a large electric current flows through the loops, it will turn ordinary metal into a magnet. The motor shell also has a magnet on it. When electricity flows through the electromagnet, it repells from the magnet on the motor shell and the shaft spins. If the fan is on the motor shaft then its blades will create airflow.



Experiments

Consider this circuit (which is project 2):



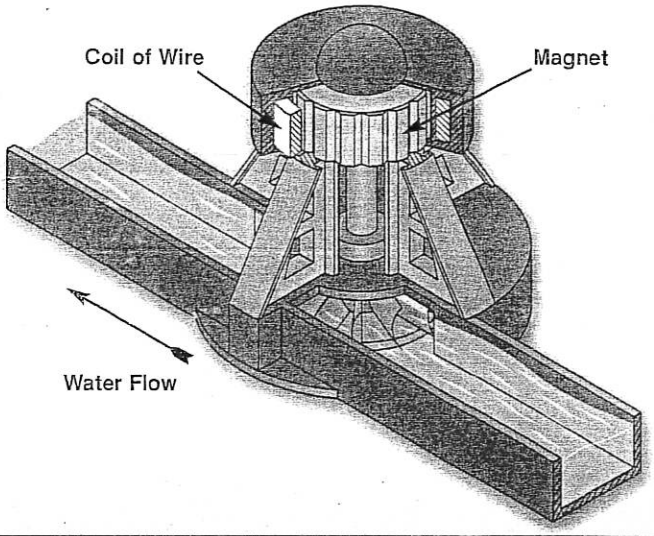
When the switch is on, current flows from the batteries through the motor making it spin. The fan blades will force air to move past the motor. Be careful not to touch the motor or fan when it is spinning at high speed.

Motors are used in all electric powered equipment requiring rotary motion, such as a cordless drill, electric toothbrush, and toy trains. An electric motor is much easier to control than gas or diesel engines.

The electromagnetic effect described above also works in reverse - spinning a magnet next to a coil of wire will produce an electric current in that wire. This is what happens in a **generator**, which uses mechanical motion to create electricity. In an electric power plant, high-pressure water (from a dam) or steam (heated by burning oil or coal) is used to spin a paddlewheel linked to magnets. The magnets create an electric current in a coil of wire, which is used to power our cities.

In theory, you could connect your Snap Circuits motor directly to the 2.5V lamp and spin the fan blade with your fingers to light the lamp. In reality, it would be impossible for you to spin the motor fast enough to produce enough current to get even a glimmer of light from the lamp.

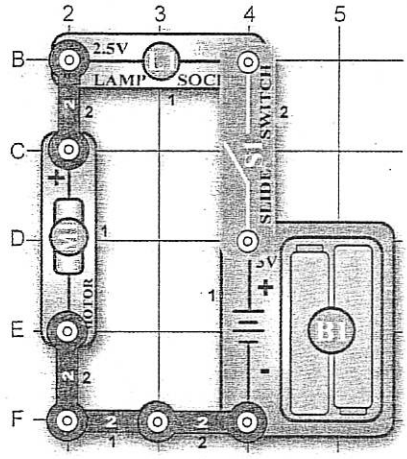
To summarize, **a generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion.**



2-2 Motor Circuits

Experiments

Consider this circuit (which is project 5):

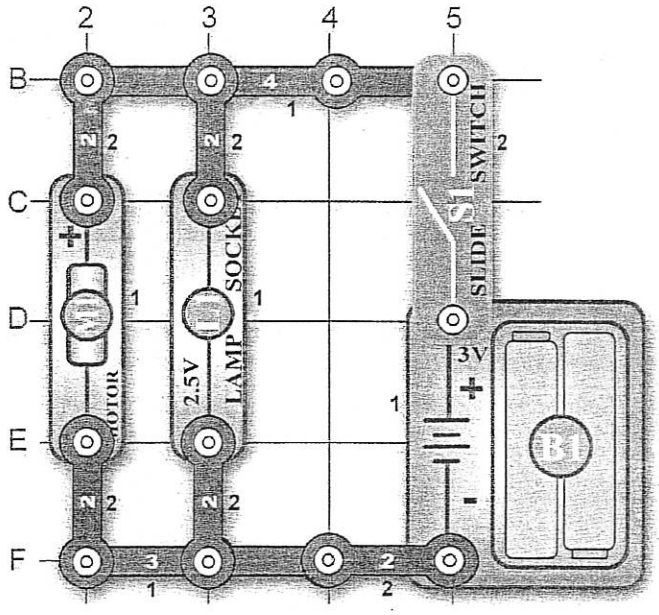


If the switch is on, the lamp will light and the fan will spin.

The lamp and motor are in series, so the voltage from the batteries will get divided between them. In this circuit more of the voltage will be used at the lamp than at the motor.

If the fan was not on the motor then the motor would spin much faster but the lamp would not be as bright. The motor needs more voltage to spin faster, so there is less voltage available to light the lamp.

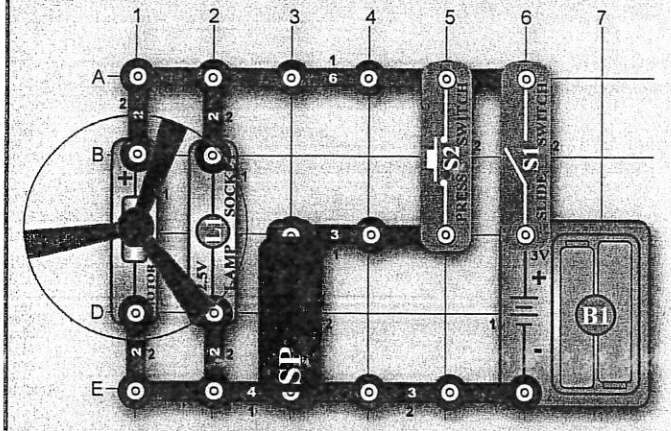
Consider this circuit (which is project 6):



If the switch is on, the lamp will light and the fan will spin. This circuit has the lamp and motor in parallel, so the full voltage from the batteries would be applied to both. So the fan would spin faster than for the circuit in project 5, which divided the battery voltage between the lamp and motor.

Experiments

Now consider this circuit (which is project 80), with the fan on the motor:



In this circuit the lamp will not be at full brightness, even though the full battery voltage is applied to it. Do you know why?

Remember that as the circuit current increases, the voltage produced by a battery is reduced. The motor draws a high current, very high when it first starts up with the fan on. The chemical reaction in the batteries can't supply such a high current, so the battery voltage (electrical pressure) drops.

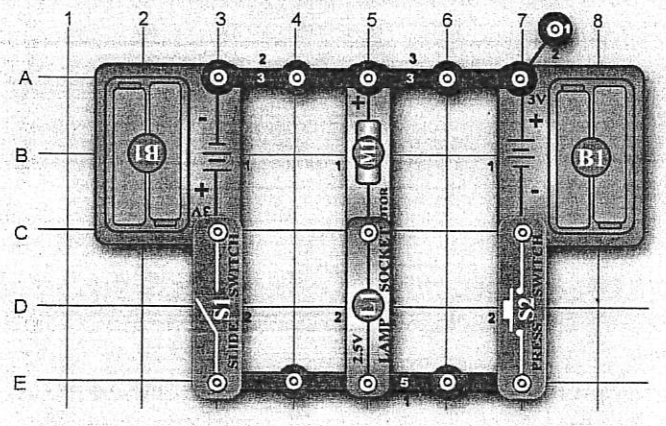
If your instructor has a meter to measure voltage, ask him to measure the battery voltage with the slide switch on and off. You would see the voltage drop to under 2.5V when the switch is on.

Push the press switch to add the speaker to the circuit and increase the circuit current even more. This will make the lamp less bright. Take the fan off the motor and turn on the switch again. The lamp will be brighter now.It doesn't take as much current to spin the motor without the fan, so the battery voltage doesn't drop much.

You know that the AA batteries used to power your snap circuits have + and – markings on them, called **polarity** markings. The chemical reaction in the batteries only makes the electric current flow in one direction. To make the current flow in the other direction you just reverse the batteries (all batteries in the same circuit must be reversed). The motor also has + and – markings, because if the direction of current flow through is reversed than the motor will spin in the opposite direction (reversing the electric current reverses the magnetic field generated, which reverses the direction the shaft spins). The lamp, switch, and wires have no such + and – markings on them because they work the same regardless of which way the current is flowing.

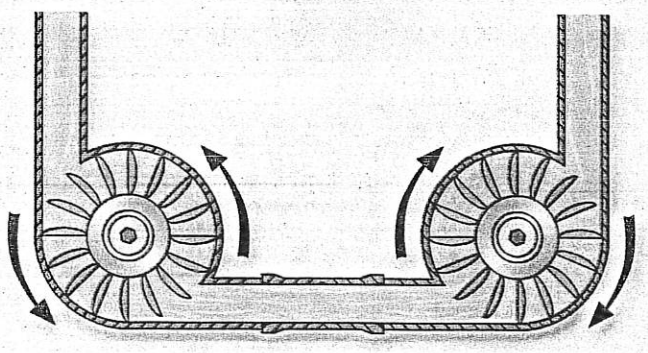
Experiments

Consider this circuit (which is project 262):



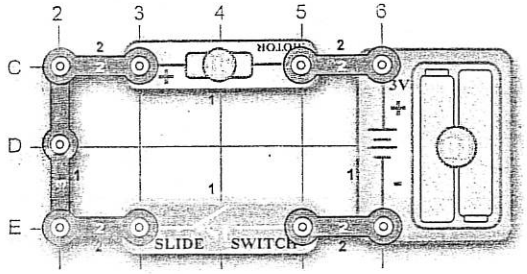
If the slide switch is on, the fan will spin to the left. If the press switch is on, the fan will spin to the right. The slide and press switches apply opposite voltages to the circuit. The lamp lights in either case, since it is not affected by the direction of current flow.

What happens if both switches are on? Nothing happens, just as if both were off. The opposite voltages from the batteries cancel each other out. Think of this as two pumps trying to pump water through a pipe in opposite directions.



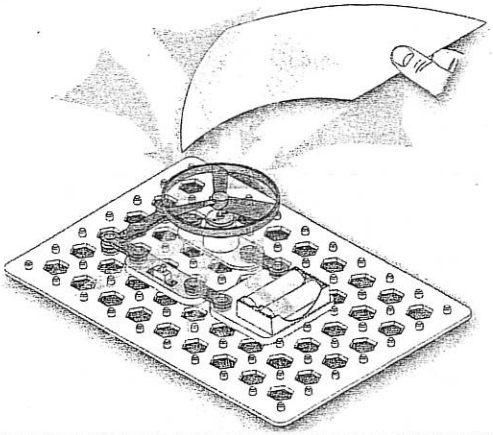
Experiments

Consider this circuit (which is project 11):



If the switch is turned off when the motor is spinning at full speed, the fan will rise into the air. Be careful not to touch the motor or fan while it is spinning at high speed. In this circuit the fan blades suck in air and push it down to the table.

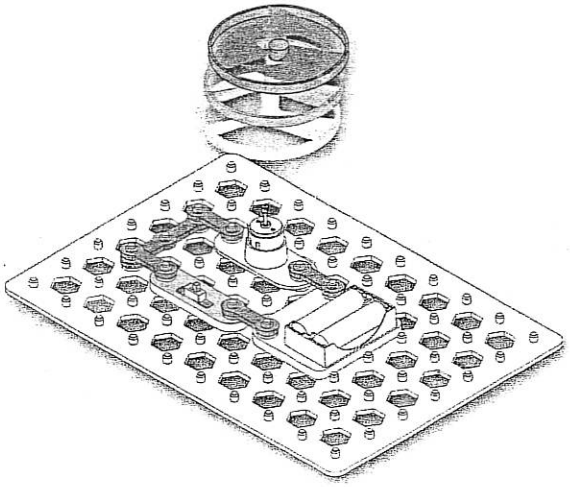
If you hold a sheet of paper above the fan, you will see it get sucked toward the fan.



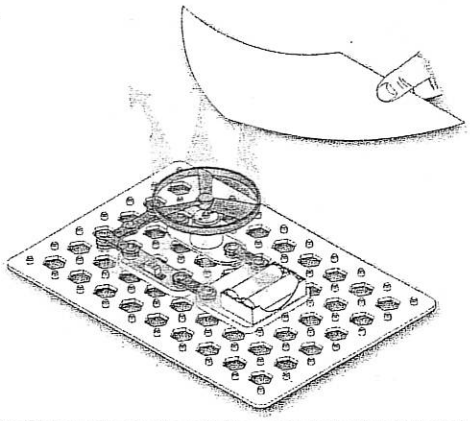
How does the fan rise? Think first about how you swim. When your arms or legs push water behind you, your body moves ahead. A similar effect occurs in a helicopter - the spinning blades push air down, and create an upward force on the blades. If the blades are spinning fast enough, the upward force will be strong enough to lift the helicopter off the ground.

While the switch is on, the motor rotation locks the fan on the motor shaft. The fan does not spin fast enough to lift the entire circuit off the ground. Sometimes there may be enough lift to make the base grid hover around the table like a puck on an air hockey table.

When the motor is turned off, the fan unlocks from the shaft. The fan rises into the air like a helicopter, since it is no longer held down by the weight of the full circuit.

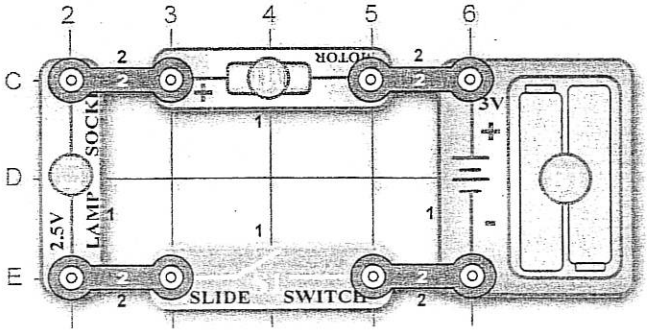


If the motor polarity were reversed (+ on the right), the fan would never fly. The fan blades are sucking in air around the motor and pushing it straight up. If you hold a sheet of paper above the fan, you will see it get pushed up and away from the fan.



Experiments

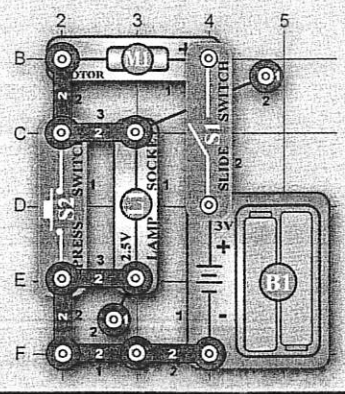
Consider this circuit (which is project 12):



By placing the lamp in series with the motor, the voltage at the motor is reduced. The motor speed will be reduced, so the fan will probably not fly off.

Experiments

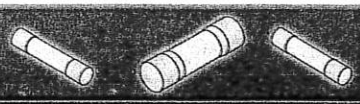
Consider this circuit (which is project 13):



If the slide switch (S1) is on, the fan spins and the lamp lights. If the press switch (S2) is also on, then the fan will spin faster but the lamp will be off. In this case, the full battery voltage is applied to the motor, instead of being divided between the motor and lamp.

This is one way of controlling the speed of a fan. Commercial fans do not use this method because the lamp produces heat and wastes energy. Commercial fans change the amount of voltage applied to the motor using other methods.

2-3 Fuses

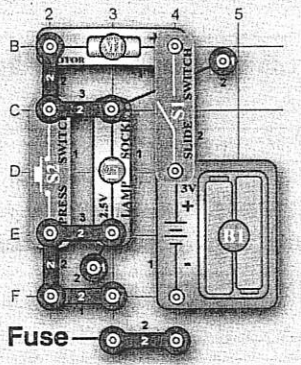


Occasionally electronic products/components break due to people using them incorrectly, accidents, natural storms, bad design, or component failures. Often the problem is a short circuit, which results in an excessively high current flow. This high current can overheat components in the product enough to damage them, make them explode, or start a fire.

A **fuse** is usually a special wire that breaks ("blows") when too much current flows through it. A "blown fuse" shuts down the product before anything can overheat or cause a fire. Although a "**blown fuse**" prevents the product from working, fuses are easy to replace.

Experiments

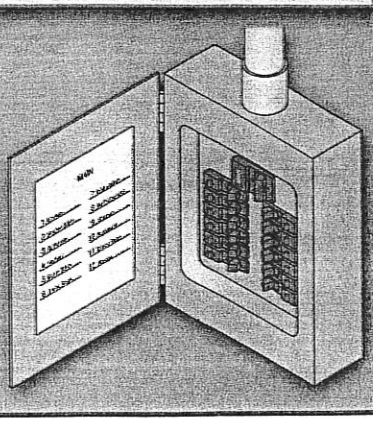
Imagine that one of the 2-snap wires in the previous circuit is a fuse (as in project 14):



If the circuit is operating properly then the "fuse" acts as a 2-snap wire. However if the motor breaks and suddenly becomes a short circuit while both switches are on, then there will be nothing to limit the current in the circuit. A very high current will flow from the batteries, and would damage them if it continues. This excessively high current will "blow" the fuse, creating an open circuit just like turning off the slide switch would do. This will protect the batteries from damage. The motor can then be repaired and the fuse replaced.

Fuses are very important and most electronic products have one. Products using electricity supplied by the electric company are usually required to have them because the high voltages and currents available here can cause severe damage and fires. Small battery-powered products usually do not have fuses because the batteries in them are not powerful enough to cause harm.

While many fuses must be replaced when blown, flipping a switch can reset some types. Every home has an electrical box of such fuses, to isolate any problems in one room from the rest of the house and your neighbors. But these fuses protecting your home take a much higher current to "blow" them than a fuse used in a radio.



2-4 Your Electric Company

Batteries are widely used because they are easy-to-use, safe, and portable. For example, snap circuits can be used on a camping trip in a remote wilderness as long as you have batteries. You can even take along spare batteries because they are small and easy to carry.

What if you wanted to take a microwave oven on the camping trip? A microwave oven uses a lot of electricity, so the batteries for it would be large, heavy, expensive, and wouldn't last long. Heavy, high-power products like microwave ovens are not moved often.

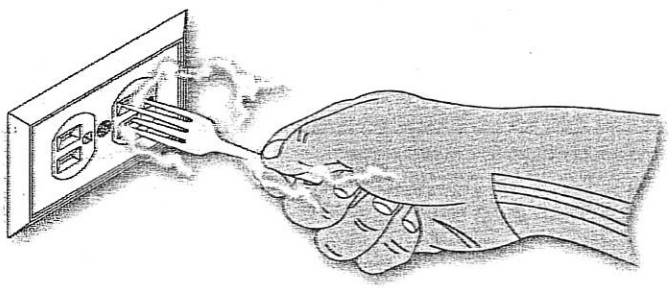
Only a tiny portion of the electricity used in our world comes from batteries. The rest is produced at enormous electric power plants, operated by your local electric company. The electricity from these power plants is available at the electrical outlets in the walls of your home.
The cost of electricity from the electric company is much less than the cost of electricity from batteries.

The voltage of the electricity supplied by the electric company is 120V, much higher than the voltage of the batteries in snap circuits. This is available at each of the electrical outlets in your home. The current available is very large, since it must power products like dishwashers and TVs.

A "**blackout**" occurs when part of a city is cut off from the power plants supplying it with electricity. The city will appear "black" from the air at night, since there are no electric lights on. This is usually due to accidents or storms, but is also done to confuse attacking bombers in war.

A "**brownout**" occurs when power plants cannot supply enough current to a city during high demand, and must reduce the voltage below 120V. This sometimes occurs on hot days in summer when everyone is using their air conditioners.

Our lives are much easier and more fun by having such power available by simply plugging into an electrical outlet. This amount of electricity is also very dangerous, and it will kill anyone who abuses it. While accidents involving electricity are rare, they kill people every year. **Never put anything into an electrical outlet except an electrical plug**. Battery-powered products are safe, since small batteries are too weak to hurt people.



The protective plastic around the wires to plug in a lamp are all that protects you from the full power of electricity. Damaged electrical cords should always be unplugged and repaired. Remember that electricity travels through water, so don't use electric products while taking a bath (battery-powered products are fine).

Your home has fuses that automatically turn off the electricity in your home if there is an electrical problem, such as a short circuit. These fuses prevent electrical problems in your home from affecting your neighbors, but they do not protect you.

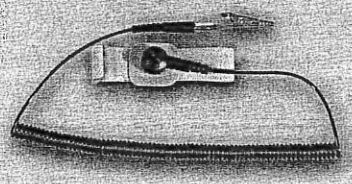
2-5 Static Electricity

You may have noticed that sometimes you can get an electric "zap" in your home or school, how clothes stick together when you take them out of the dryer, or when taking off a wool sweater on a dry day. Occasionally differences in electrical charge build up between things, called static electricity. The things, which might include your body, are storing electrical charge. They might store a very small amount of electrical charge at high voltage. This is just like a cloud storing electrical charge before a thunderstorm.

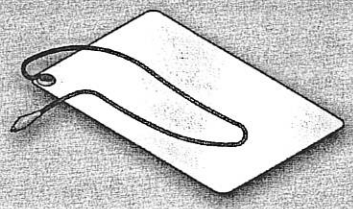
The name "static" is used to describe the electrical charge build-up because the charge is not moving around to disperse. "Static cling" refers to how clothes sometimes cling to each other in the dryer, due to static electricity. Static electricity in the atmosphere causes the "static" (erratic noises) you hear on your AM radio when reception is poor.

Static "zaps" occur when an electrical current flows to equalize the charge difference. Though the voltage might be high, the current is small and the duration is short. The actual "zap" occurs because the voltage is high enough to "jump" across a high-resistance material (usually air), making a small spark as it happens.

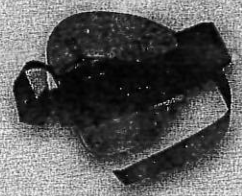
Though the "zap" might sting you briefly, these effects do not harm people. However, these static zaps can damage some types of sensitive electronic components and electronics manufacturers have to protect against it. Such protection includes static wrist straps, conductive floor matting, and humidity control. The parts in snap circuits will not be damaged by static.



Anti-Static Wrist Strap



Anti-Static Floor Mat



Anti-Static Ankle Strap

In the same way, clouds can build up a static electrical charge. This charge might become very large, and it is spread out over the enormous volume of the clouds. Lightning occurs when this electrical charge discharges into the ground, and can be very destructive. Lightning is looking for the lowest-resistance path from the clouds to the ground.

Do you know why you often "see" lightning before you "hear" it? It is because light travels faster than sound.

Since people have less resistance than air, standing in an open field during a thunderstorm is very dangerous. Houses and other buildings have "**lightning rods**" to protect them, which are metal bars from the roof into the ground. Their purpose is to encourage lightning to go through the rods to the ground, instead of going through the house to the ground.

Large aircraft can build up a large electrical charge during a long flight. A wire similar to a lightning rod is usually connected to an aircraft shortly after landing, as a precaution against static zap.

Static Electricity Example:

Comb your hair vigorously with a plastic comb and hold the comb near some little (1cm x 1cm) scraps of paper to pick them up OR tilt the comb near a slow, steady stream of water from a faucet and see how the water bends towards it.

Quick Quiz

1. List all the products in your home that use an electric motor.
2. Name some examples of static electricity.

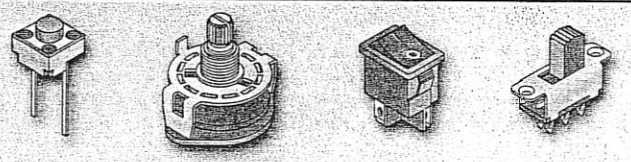
2-6 Types of Lamps

The lamps in Snap Circuits are **incandescent** type, the same as the larger lamps in your home. The bulbs contain a special high-resistance wire, called the **filament**. When an electric current passes through it the wire gets so hot that it glows. Heat is also produced, and the glass bulb prevents the filament from reacting with oxygen in the air and burning. When the voltage rating of an incandescent bulb is exceeded, the filament gets so hot it burns out. Filaments are usually made of tungsten, since ordinary copper would melt.

The **fluorescent** light bulbs that come in white 4 ft. tubes are the standard room lights for offices and schools. They pass electric current through a gas, usually neon. This gas emits light as the electricity passes through it, similar to how a tungsten wire does. Although larger and more expensive than ordinary incandescent lamps, they are more efficient at converting electricity into light.

The difference in heat produced between incandescent and fluorescent light bulbs might surprise you. Find a fluorescent bulb and feel the heat coming off it; you won't feel much. Find an incandescent lamp THAT HAS BEEN OFF FOR A WHILE and turn it on. Feel the heat it produces; it soon becomes too hot to touch. Only about 5% of the electricity used by incandescent bulbs is converted into light. Without the more efficient fluorescent bulbs, our society of office buildings might have been much different.

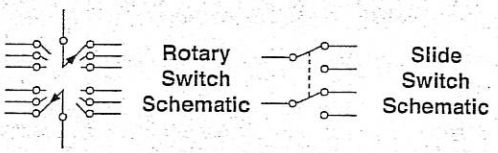
2-7 Types of Switches



Push Button Rotary Rocker Slide

The slide and press switches included in snap circuits are simple switches, more complex types are also available. Switches come in almost every shape and size imaginable. There are membrane, rocker, rotary, DIP, locking, and non-locking types just to name a few.

Very often, a single switch is used to make many different connections. The combinations of connections for a switch are indicated in the symbol for it. Here are some examples:



2-8 Electricians

There are many different ways of using electricity, so there are many types of people who work directly with it. The main categories are electricians and engineers/technicians. Although many people think of these as being the same career, they are actually very different. They attend different schools, use different tools, and work in different places.

Electricians are the people who install electrical wiring into homes and businesses. Electricians deliver the electricity to your home to be used. It takes a lot more electricity to operate everything in a building than to operate a computer or radio, so safety is very important and the equipment they use can handle high levels of voltage and current. Buildings are not easy to re-wire, so the wiring must be reliable and safe for many years. Electricians are trained in union and trade schools. Local government licenses them because buildings must be wired as per strict local building codes to be sure they will be safe even after many years.

Electrical/electronics engineers and technicians design and develop products that will use the electricity that electricians have brought to them. Voltages and currents are much lower and safer, but circuits can be much more complex (like computers) and technologies change quickly. Electronic products are mass-produced in factories, unlike building wiring which must be installed in the building. Engineers are trained in colleges and technicians are trained in trade schools. Government does not regulate them but products must meet industry safety standards.

Summary

Summary of Chapter 2:

1. An electric current flowing in a wire has a magnetic field.

2. A generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion.

3. A fuse is a special wire that breaks when an excessively high current flows through it, used for safety.

4. Electrical outlets are 120V, and can supply enough current to kill people.

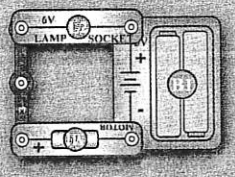
5. Static electricity can cause clothes to stick together. Lightning occurs when static electricity in clouds discharges into the ground.

6. Only a small amount of the electricity used by light bulbs is converted into light, the rest becomes heat.

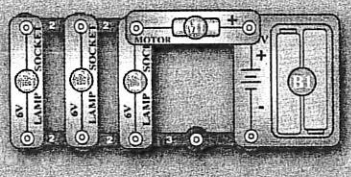
Quiz

Chapter 2 Practice Problems

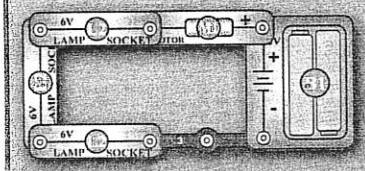
1. Fuses are needed for all of the following reasons except:
   A. They improve circuit performance.
   B. To prevent an electrical problem from starting a fire.
   C. To limit the current in a circuit.
   D. People don't always use products correctly.
2. All of the following are caused by static electricity except:
   A. Lightning
   B. Erratic noises interrupting music on your AM radio.
   C. Clothes sticking together in the dryer.
   D. Blackouts
3. Which circuit will spin the fan the fastest? Which will spin fan the slowest?



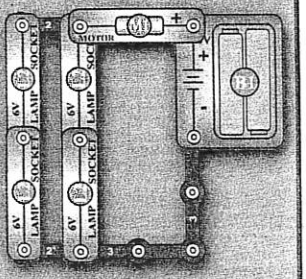
A



B

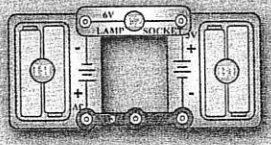


C

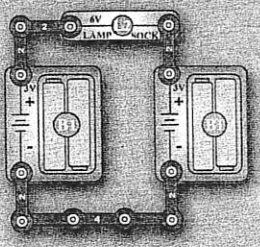


D

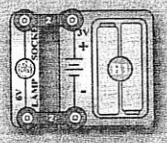
4. Which circuit will make the lamp the brightest?



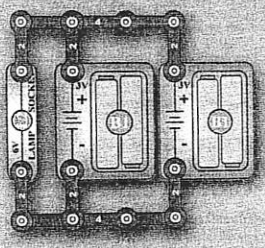
A



B



C



D

Answers: 1. A, 2. D, 3. B/C, 4. A

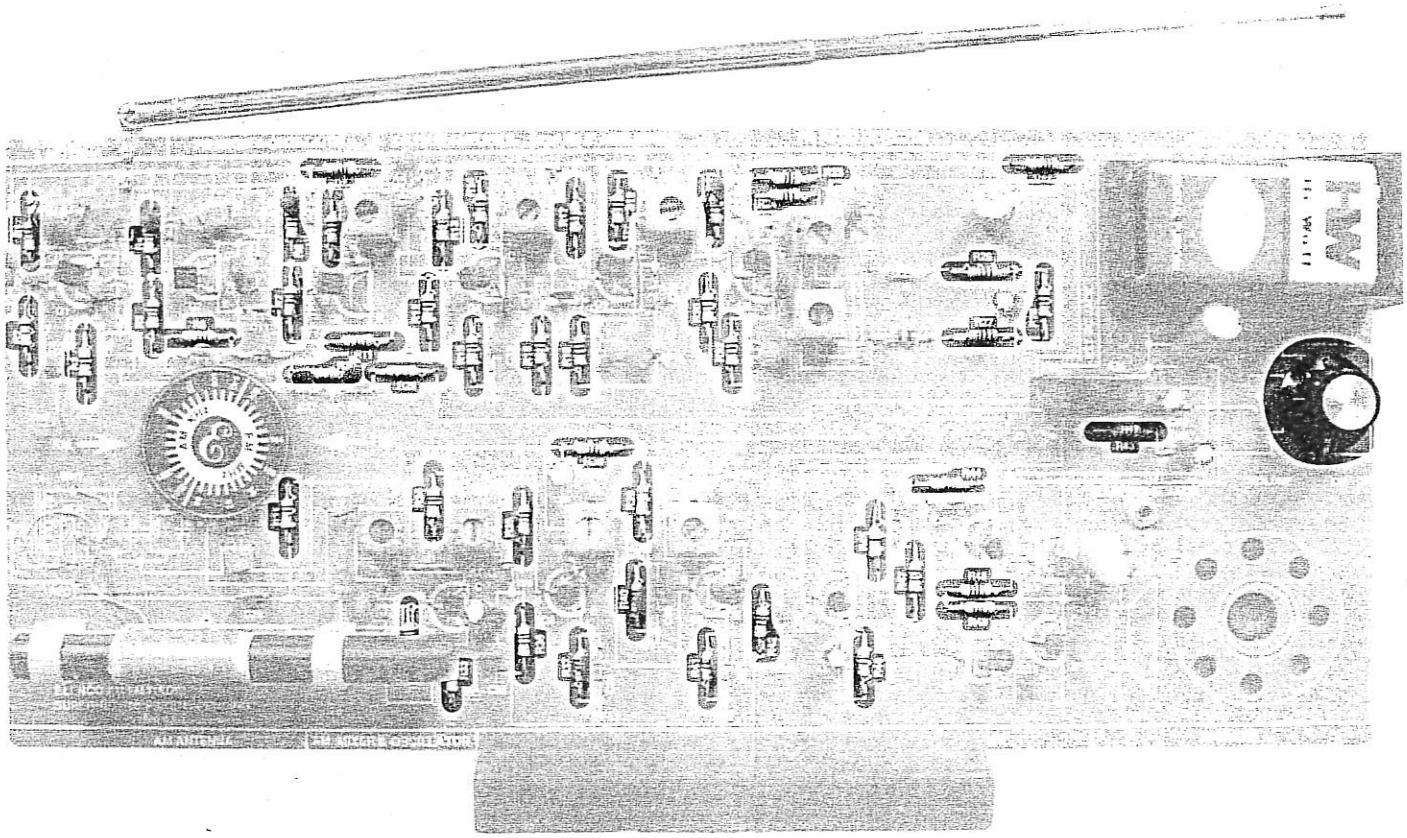
CHAPTER 3: RESISTANCE

Learn By Doing®

All of the circuits and components studied in chapters 1 and 2 are commonly used by electricians, though the actual parts used will be for much higher voltages and currents than the snap circuit parts representing them. Electricians are concerned with getting the electricity to where it will be used as efficiently as possible, without wasting energy.

In consumer products like toys, radios, and computers, electronics engineers and technicians want to control how it is used.

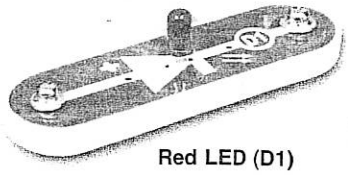
In this chapter you will learn about resistors, which are used to limit and control the flow of electricity. As an example of how important resistors are in electronics, consider a typical AM/FM radio:



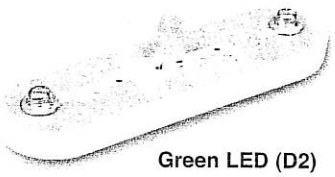
This radio contains 50 resistors, which are highlighted. The radio needs every one to operate properly. Televisions contain hundreds of resistors, and computers contain even more.

Introducing New Parts

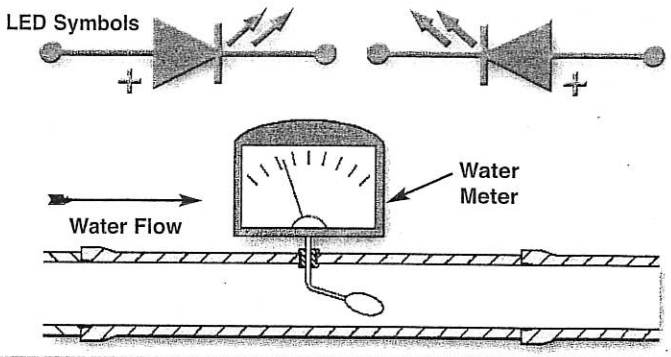
Snap circuits includes both a red and a green LED. The arrow in the symbol of the part includes which direction it allows current to flow in (referred to as the forward direction):



Red LED (D1)

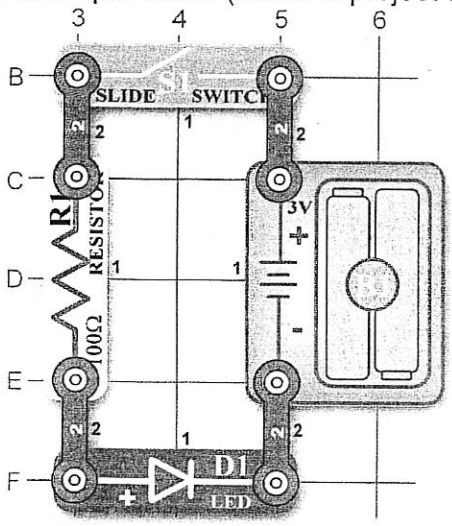


Green LED (D2)



Experiments

Consider this simple circuit (which is project 7):

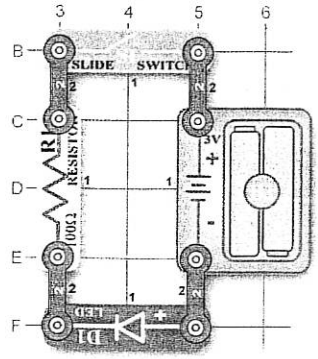


If the switch is on, the LED (D1) will light. The resistor limits the current so that the LED is not damaged (never place an LED directly across the battery). The LED is just like a lamp here, except that it would not be as bright and would use less battery power. Also, an LED appears much brighter when viewed from above than from the side. LEDs concentrate most of their light in one direction, unlike a light bulb which emits light nearly equally in all directions.

If the resistor value in the circuit were increased, the LED would become much dimmer. For example, if the 100Ω resistor (R1) was replaced with the 10KΩ resistor (R4), the LED light could only be seen if the room was very dark.

Experiments

What would happen if the LED position were reversed, in a circuit like this:

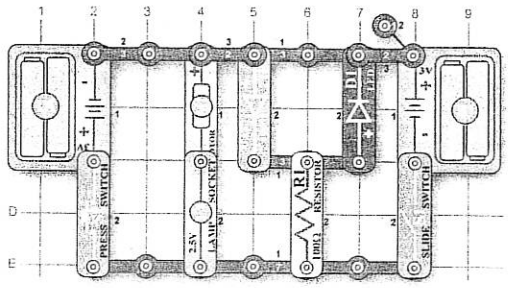


Nothing will happen. The LED prevents any current from flowing, and the LED will be off.

Other snap circuits projects related to this subject:
175

Experiments

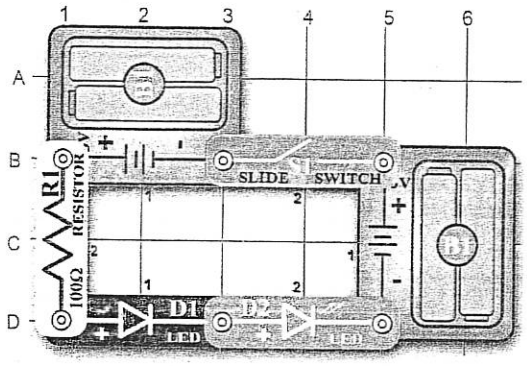
For another example, consider this circuit (which is project 276; be sure the fan is on the motor):



The two sets of batteries will drive the fan in opposite directions, depending on which switch is turned on. Only one LED will light, indicating direction. Unlike the LEDs, the lamp has no polarity and will light in either case. Note that if both switches are on, a short circuit is created and nothing will happen (but the batteries get weaker).

Experiments

Now consider this circuit (which is project 102, redrawn):



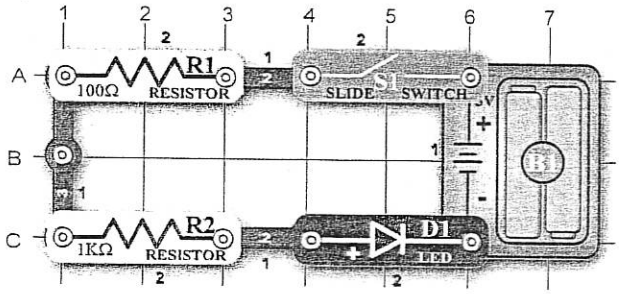
The LEDs would have the same brightness. The same current will flow through both, since they are in series.

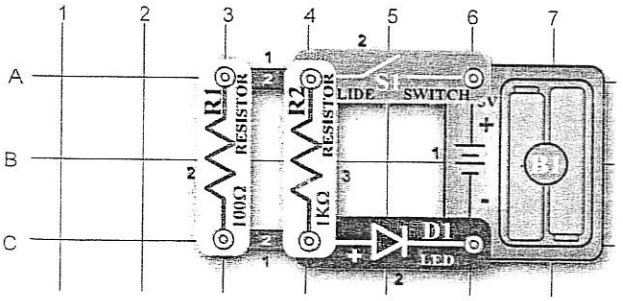
Can you guess why this circuit uses two sets of batteries instead of just one? Each LED has a "turn-on" threshold of about 1.5V that must be exceeded before current will start to flow, after that the brightness depends on the current. When two LEDs are in series the combined threshold is 3V, so one set of batteries will not exceed the threshold by any noticeable degree. This threshold is due to the semiconductor material used in its construction.

LEDs are used as indicator lights in a wide range of electronic products. They are more efficient than ordinary light bulbs and so use less electricity to be seen. But they cannot handle high currents, and so cannot be used to light up a room like light bulbs do.

3-3 Resistors in Series & Parallel

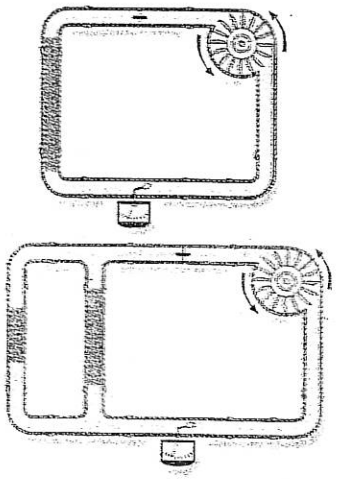
Consider these two mini-circuits:





The first circuit has the 100Ω and 1KΩ resistors in series, the second circuit has them in parallel. Which circuit will make the LED brighter?

Just think of the resistors as rock piles slowing down the flow of water in a pipe:



From the water diagrams, it should be easy to see that the circuit with the resistors in parallel will have the brighter LED. You can build these mini-circuits with your snap circuits parts to prove this.

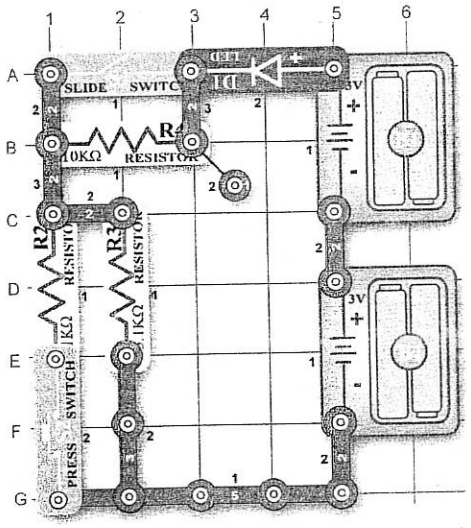
Placing resistors in series increases the total resistance, and so decreases the current to the LED. Resistors in series add together. **Placing resistors in parallel decreases the total resistance**, and so increases the current to the LED.

Advanced students can compute the total resistance as follows:

$$R_{series} = R1 + R2 + R3 + \ldots \qquad \frac{1}{R_{parallel}} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots$$

The total series resistance is greater than the biggest resistor, and the total parallel resistance is smaller than the smallest resistor.

a review, consider this circuit (which is project 173):



If the slide switch (S1) is on, then the LED will be on but not very bright as the 5.1K resistor limits the current. Turning off the slide switch places the 10K resistor in series and the LED becomes very dim. If both switches are on, the 1K resistor is in parallel with the 5.1K and so the LED becomes very bright.

You've learned that when you increase resistance in a circuit, less current flows (making an LED dimmer). This relationship between voltage, current, and resistance is the most important one in electronics. It is known as **Ohm's Law** (after George Ohm who discovered it in 1828):

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

The most basic rules for analyzing circuits as known as **Kirchhoff's Laws** (known after Gustav Kirchhoff, who stated them in 1847):

1. The total voltages driving a circuit must equal the voltage drops within it.
2. All current flowing into a point must flow out of it.

The "**power**" of electricity is a measure of how much energy is moving through a wire. It is expressed in **Watts** (W, after James Watt for his work with engines). It is a combination of the electrical voltage (pressure) and current:

Power = Voltage x Current

OR

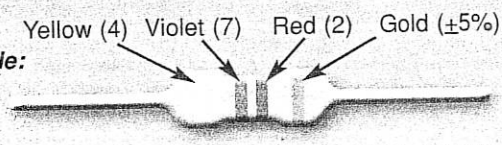
$$\text{Power} = \frac{\text{Voltage} \times \text{Voltage}}{\text{Resistance}}$$

Resistor Color Code:

You may have seen the colored bands on the resistors and may be wondering what they mean. They are the method for marking the value of resistance on the part. The first ring represents the first digit of the resistor's value. The second ring represents the second digit of the resistor's value. The third ring tells you the power of ten to multiply by, (or the number of zeros to add). The fourth and final ring represents the construction tolerance. Most resistors have a gold band for a 5% tolerance. The colors on the right are used to represent the numbers 0 through 9.

COLOR	VALUE
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Example:



4,700Ω
OR
4.7kΩ

Use the color code to check the values of the five snap circuits resistors. They are all 5% tolerance.

3-4 Resistance

Just what is Resistance? Take your hands and rub them together very fast. Your hands should feel warm. The friction between your hands converts your effort into heat. **Resistance** is the electrical friction between an electric current and the material it is flowing through; it is the loss of energy from sub-atomic particles as they move through the material.

You can also compare resistors to the friction with the ground when you walk. If there is too much friction (like two feet of snow) you have to go very slow or get stuck. If there is too little friction (like ice) then you have no control and will slip and fall.

Resistors are made from carbon and can be constructed with different resistive values, such as the five parts included in snap circuits. If a large amount of current is passed through a resistor then it will become warm due to the electrical friction. Resistors get warm because they exert control by wasting power as heat. Light bulbs use a small piece of a highly resistive material called tungsten. Enough current is passed through this tungsten to heat it until it glows white hot, producing light.

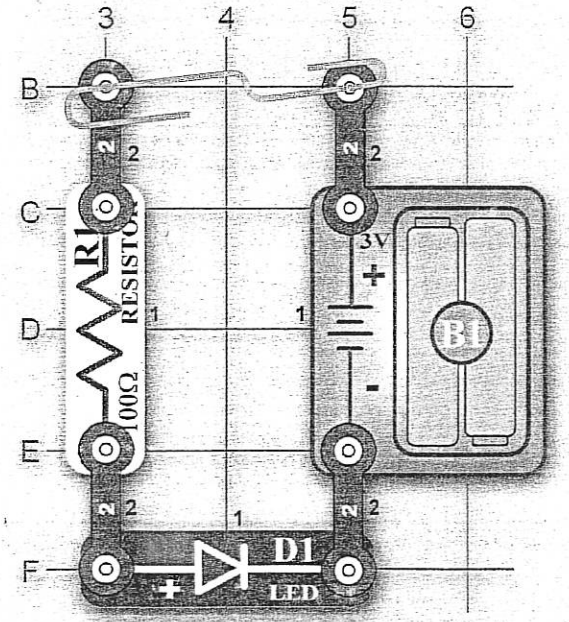
Electric stoves and heaters use resistors to change electricity into heat.

Metal wires have some electrical resistance, but it is very low (less than 1Ω per foot) and can be ignored in almost all circuits. Materials, such as metals, which have low resistance are called **conductors**. The best conductor material known is silver, but it is too expensive to be widely used. Copper is second best, and it is used in most wires and printed circuit boards in the electronics industry.

Materials such as paper, plastic, and air have extremely high values of resistance and are called **insulators**.

Experiments

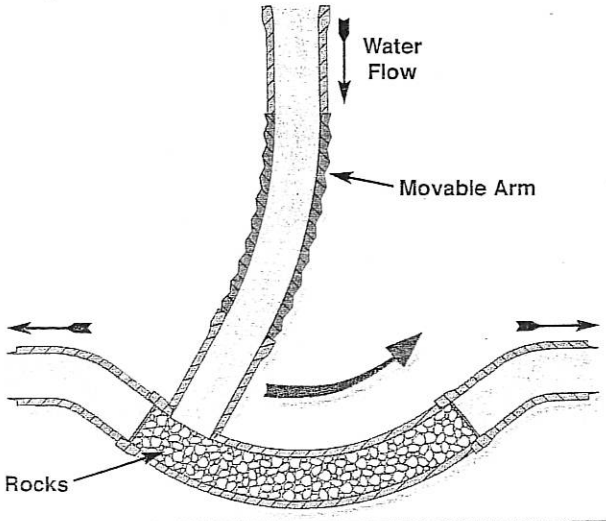
You can use snap circuits to test whether materials are conductors or insulators. Consider this simple circuit (which is project 9):



Place any material across the 2-snap wires (the circuit shows a paperclip). If the LED is bright then it is a conductor, if the LED is off then it is an insulator.

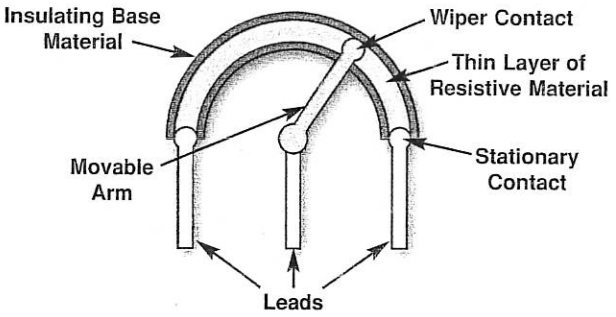
3-5 The Adjustable Resistor

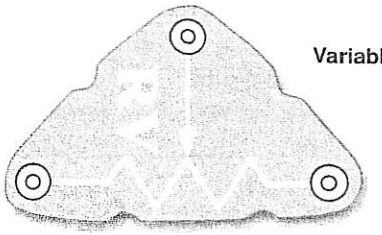
A switch is used to turn the electricity on and off just like a valve is used to turn the water on and off. But there are many times when you want some water but don't need all that the pipe can deliver, so you control the water by adjusting an opening in the pipe with a faucet. Unfortunately, you can't adjust the thickness of an already thin wire. But you could also control the water flow by forcing the water through an adjustable length of rocks, as in the rock arm shown below.

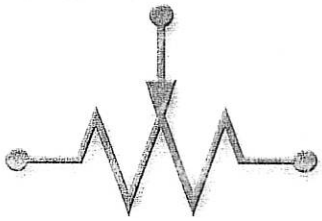


Introducing New Parts

In electronics we use an adjustable resistor. This is a normal resistor (50KΩ in snap circuits) with an additional arm contact that can move along the resistive material and tap off a portion of it.

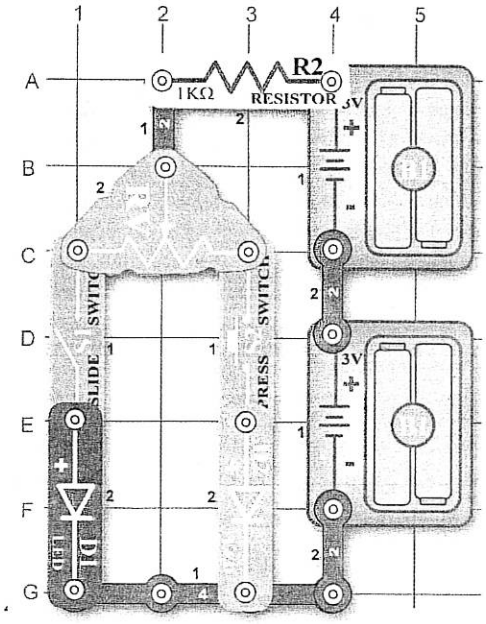






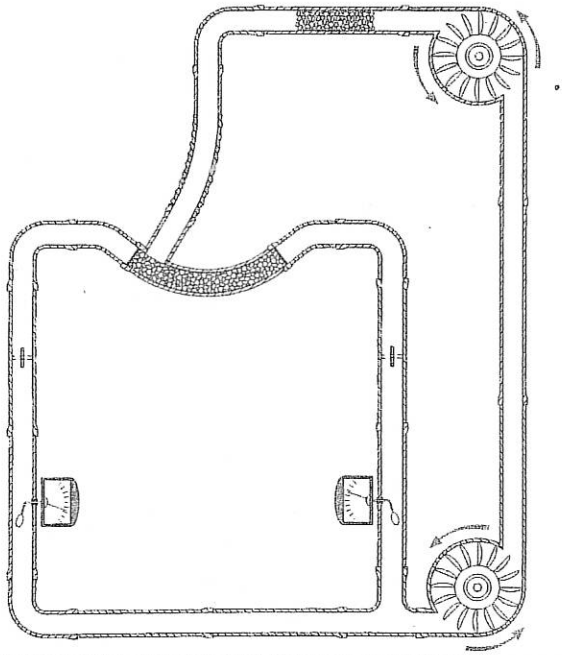
Experiments

Consider this circuit (which is project 172):



If the slide switch and the press switch are both on, moving the adjustable resistor's control lever around will adjust the brightness of the LEDs. When the adjustable resistor is set to one side, that side will have low resistance and its LED will be bright while the other side will have high resistance and its LED will be dim or off. The 1K resistor (R2) limits the current so the LEDs cannot be damaged.

This circuit can also be thought of as if it were water flowing through pipes:



3-6 The Photo Resistor

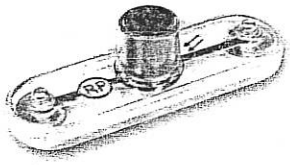
Some materials, such as Cadmium Sulfide, change their resistance when light shines on them. Electronic parts made with these light-sensitive materials are called photoresistors. Their resistance decreases as the light becomes brighter.

Introducing New Parts

Snap circuits includes one photoresistor. Its resistance value changes from nearly infinite in total darkness to about 1KΩ when bright light shines directly on it. Note that a black plastic case partially shields the Cadmium Sulfide part.

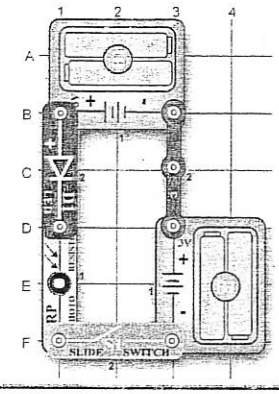
Photo Resistor (RP)

Photo Resistor Symbol



Experiments

Consider this circuit (which is project 272):



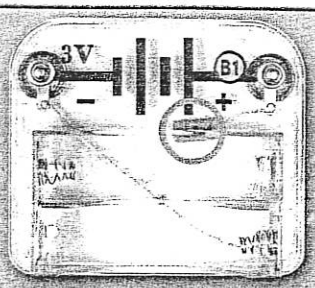
The brightness of the LED depends on how much light shines directly on the photoresistor. If the photoresistor were held next to a flashlight or other bright light, then the LED would be very bright.

Photoresistors are used in applications such as streetlamps, which come on as it gets dark due to night or a severe storm.

Thermistors: Resistors can also be made to change resistance as the temperature changes. These are called thermo-resistors. They are used in applications like electronic thermometers, or to compensate for other circuit characteristics that are changing with temperature.

Thermistors can also be made to act as fuses. At low currents they have only slight resistance and don't affect a circuit. High currents (due to a short circuit) cause them to heat up and greatly increase resistance, limiting the current to prevent damage.

A thermistor like this is inside each of the battery holders in snap circuits:

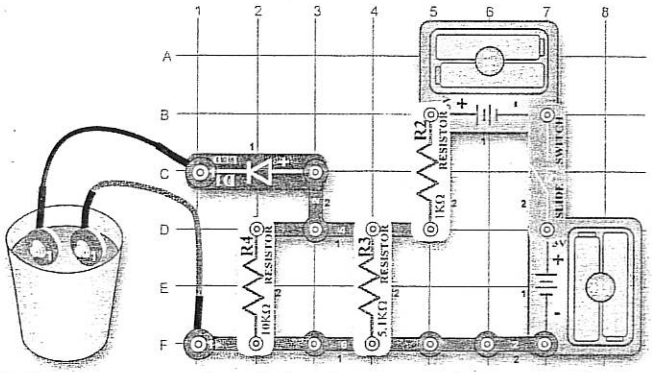


This thermistor will activate to limit current if a short circuit occurs for more than a few seconds. Running the motor for long periods will sometimes activate it, since the motor draws a high current.

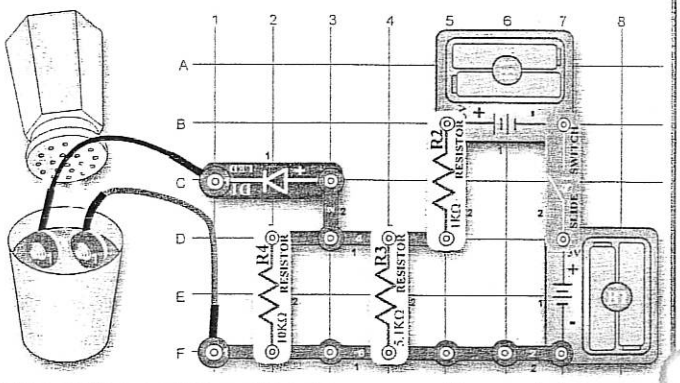
3-7 Resistance of Water

Experiments

Consider this circuit (which is project 166):



If the loose ends of the jumper wires are placed into a cup of water, the LED will be dimly lit. The circuit was designed so that the LED acts as a water detector. The brightness depends on your local water supply. If more water were added to the cup, the LED brightness would increase slightly. Adding more water is like placing more "water resistors" in parallel; and so decreases the total resistance. Pure water (like distilled water) has very high resistance, but drinking water has impurities mixed in that lower the resistance. What would happen if salt was added to the cup and dissolved in the water?



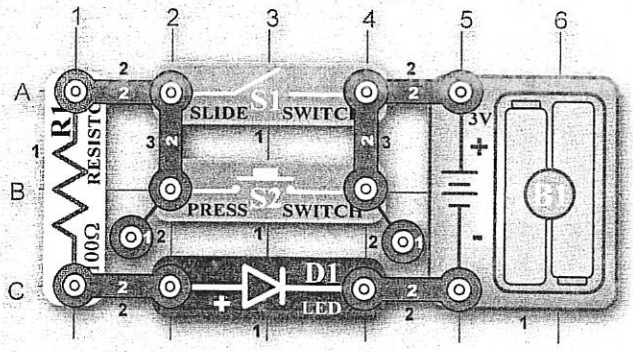
Dissolving salt in water decreases the resistance of the water, so the LED would get brighter. It could be used as a salt-water detector. Adding more water to dilute the salt could reduce the brightness.

Nearly all electricity produced eventually becomes heat. All currents flowing through resistors produce heat in them. Light from a lamp or TV produces heat in whatever it shines on. All the circuits in a computer produce heat, and most computers have vents to get this heat out.

3-8 Introduction to Logic

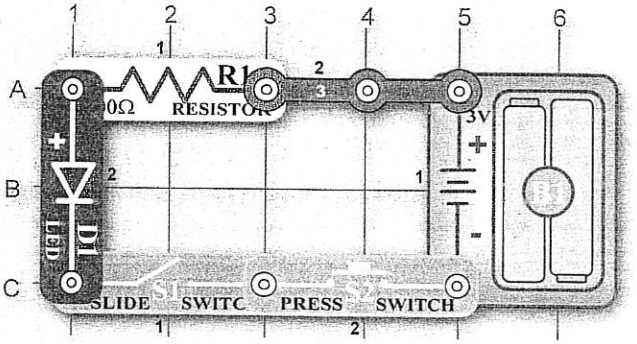
Experiments

Consider this circuit (which is project 47):



If the slide switch OR the press switch is on, the LED lights up. This is called an OR circuit. While this may seem very simple and boring, it represents an important concept in electronics. Two switches like this may be used to turn on a light in your house. You could also have more than two switches and the circuit would function the same way.

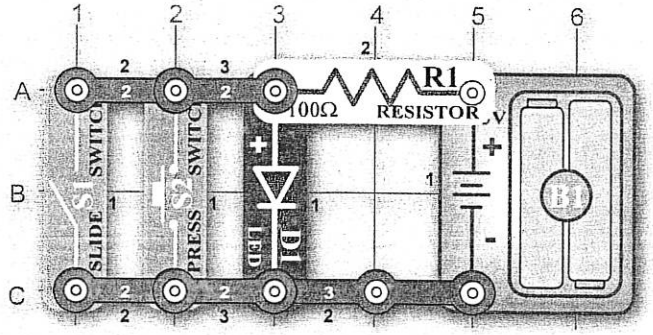
Now consider this circuit (which is project 48):



If the slide switch AND the press switch are on, the LED lights up. This is called an AND circuit. Two switches like this may be used to turn on the same light in your house, the room switch and the master switch in the electrical box.

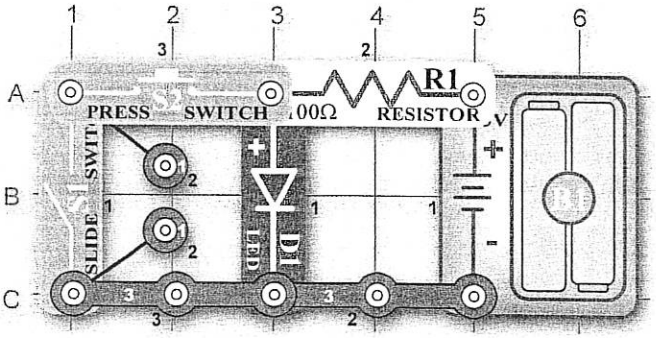
AND and OR circuits are the basic building blocks of today's computers, though transistors are used instead of switches and LEDs. Combinations of AND and OR circuits are used to add and multiply numbers together.

Now consider this circuit (which is project 49):



This circuit is the counter-part to the OR circuit, the LED lights in the opposite combinations of that circuit. Engineers called it a NOR circuit (short for "NOT this OR that").

Now consider this circuit (which is project 50):

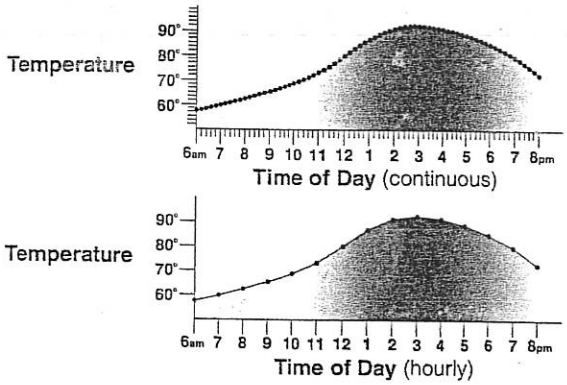


This circuit is the counter-part to the AND circuit, the LED lights in the opposite combinations of that circuit. It is called a NAND circuit (short for "NOT this AND that"). This circuit can also have more or less than two inputs, though when it only has one input it is referred to as a NOT circuit.

OR, AND, NOR, NAND and NOT circuits are all important building blocks in modern computers.

3-9 DIGITAL ELECTRONICS

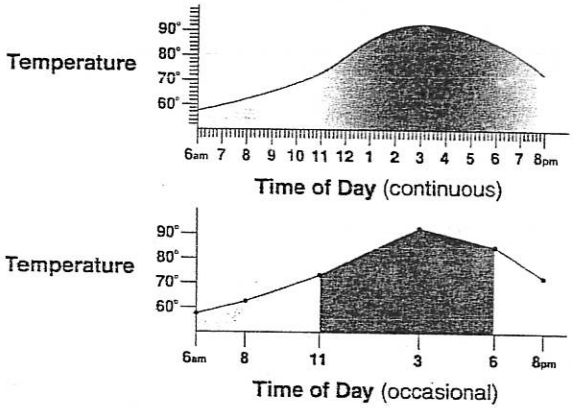
Suppose you wanted to keep a record of how the temperature outside was changing throughout the day. You could use a thermometer to measure it, and watch it continuously or just check it every hour and write it down. Your results might look something like this:



Checking it once an hour gave you a very good record of how the temperature was changing throughout the day, with much less effort than watching it all day long.

Digital electronics uses a series of numbers to represent an electrical signal. If your thermometer was electronic it might increase an output voltage as the temperature increased. It would be hard to store what that voltage was throughout the day, but easy to measure it and store it as a series of numbers. The series of numbers could be converted back into a continuous voltage later.

The accuracy of your digital representation depends on how accurately and how often you measured the original voltage. For example, you could get a better or worse representation of your temperature:



Sometimes it is easier to process information as a digital series of numbers (computers), and sometimes it is easier to use a continuously changing voltage (AM radios). Many products use both methods on the same information but at different times. The disadvantage of digital systems is that they are more complex since they have to store and process all the numbers. The advantages are that IC technology makes it inexpensive to store and process information, and digital systems are more protected from interference.

Computers store numbers in memory using vast arrays of transistors that are switched on or off. The OR, AND, NOR, NAND, and NOT gates are actually made up of transistors. These gates are used to add and multiply large numbers in tiny pieces to form the processing functions in computers.

Quick Quiz

1. Draw a schematic for a circuit using a battery set, an LED, a 50KΩ adjustable resistor, and a 1KΩ resistor. The LED must have adjustable brightness, and must never have less than 1KΩ in series with it.

Summary

Summary of Chapter 3:

1. Resistors are used to limit and control the current in a circuit.

2. Resistance is a measure of how much something opposes the flow of electricity in a circuit, and is expressed in ohms.

3. Light emitting diodes (LEDs) are one-way, low-current light bulbs. They have a turn-on threshold of about 1.5V.

4. Placing resistors in series increases the total resistance. Placing resistors in parallel decreases the total resistance.

5. In a circuit, the current equals the voltage divided by the resistance. This is known as Ohm's Law.

6. Power measures how much energy is moving through a circuit, it equals the voltage multiplied by the current and is expressed in Watts.

7. Materials which have very low resistance are called conductors. Materials which have very high values of resistance and are called insulators.

8. Photoresistors change their resistance when light shines on them.

9. All currents flowing through resistors produce heat in them.

10. OR, AND, NOR, NAND and NOT circuits are basic building blocks of computers.

11. Digital electronics uses numbers to represent an electronic signal. The accuracy of the digital representation depends on how accurately and how often the original signal was measured.

12. Computers store numbers using arrays of transistors that are switched on or off.

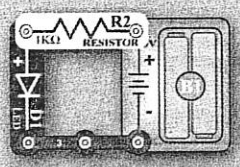
Quiz

Chapter 3 Practice Problems

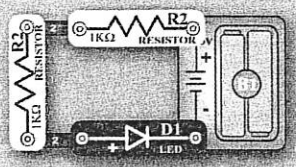
1. The following are characteristics of an LED except:
   A. They block current flow in one direction.
   B. They get brighter as current increases.
   C. They can handle very high currents.
   D. They can emit different colors of light.

2. To increase the current through a circuit, you . . .
   A. Increase the resistance.
   B. Decrease the watts.
   C. Increase the ohms.
   D. Increase the voltage.

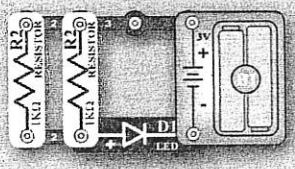
3. Which circuit will be the brightest? Which will be the dimmest?



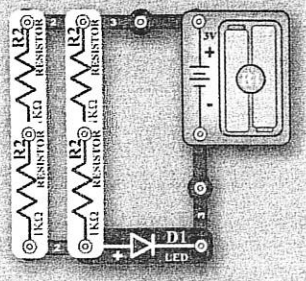
A



B

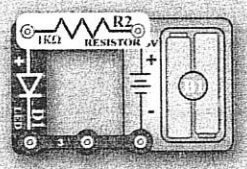


C

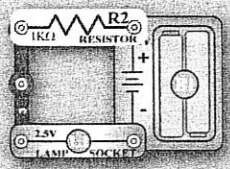


D

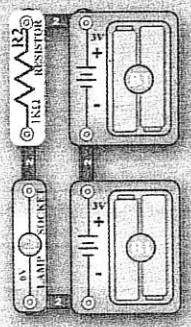
4. Which circuit will be the brightest?



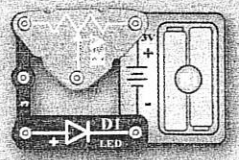
A



B



C



D

Answers: 1. C, 2. D, 3. C/B, 4. A